EXHIBIT No. 5

PART 2

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March 2, 2015

Joseph Kopta, Esquire
Kopta & Macpherson
5801 Soundview Drive
Suite 258
Gig Harbor, WA 98335

Re: *Quinn, Dennis v. Marie Ronkar*
ARCCA Case No.: 3691-015

Dear Mr. Kopta:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Dennis Quinn. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

The testimony and other available documents indicated on May 6, 2010, Mr. Dennis Quinn was the seat-belted driver of a 2006 Chrysler Pacifica traveling through an Arby's Restaurant drive-thru located at 3901 Wheaton Way in Bremerton, Washington. Ms. Marie Ronkar was the driver of a 1995 Honda Civic traveling directly behind the Chrysler Pacifica. The available documents indicated that as the Chrysler Pacifica was stopped placing an order, contact occurred between the front of the Honda Civic and the rear of the Chrysler Pacifica.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) color photographic reproductions of the subject 2006 Chrysler Pacifica
- Eight (8) color photographic reproductions of the incident 1995 Honda Civic
- Deposition Transcript of Dennis Quinn, *Dennis Quinn and Misty Quinn vs. Marie Ronkar* [April 10, 2014]
- Deposition Transcript of William Ronkar, *Dennis Quinn and Misty Quinn vs. Marie Ronkar* [April 10, 2014]
- Deposition Transcript of Marie Ronkar, *Dennis Quinn and Misty Quinn vs. Marie Ronkar* [April 10, 2014]
- Medical Records pertaining to Dennis Quinn
- Expert AutoStats data sheets for a 2006 Chrysler Pacifica
- VinLink data sheet for the incident 1995 Honda Civic
- Expert AutoStats data sheets for a 1995 Honda Civic
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

1. Identify the biomechanical failures that Mr. Quinn claims were caused by the subject incident on May 6, 2010;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2006 Chrysler Pacifica;
3. Determine Mr. Quinn's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. Quinn's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The medical records and other available documents indicate Mr. Quinn attributes the following biomechanical failures to the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic and Lumbar Spine
    - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions of the subject 2006 Chrysler Pacifica and the incident 1995 Honda Civic in association with accepted scientific methodologies. [11,12]

The reviewed photographs of the subject Chrysler Pacifica depicted scuffing/scraping damage to the rear bumper cover (Figure 1). The photographs depicted slight indentation to the upper silver bumper cover, however, there was no significant misalignment or crush. Mr. William Ronkar testified the subject Chrysler damage consisted of *"minimal"* damage including scuffing to the rear bumper cover. Mr. Quinn testified the subject vehicle damage was to the middle of the back

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9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

bumper, including scrapes and markings on the bumper. He further testified that when he had the subject Chrysler repaired he was told the *"bumper assembly that attaches to the frame was cracked.*


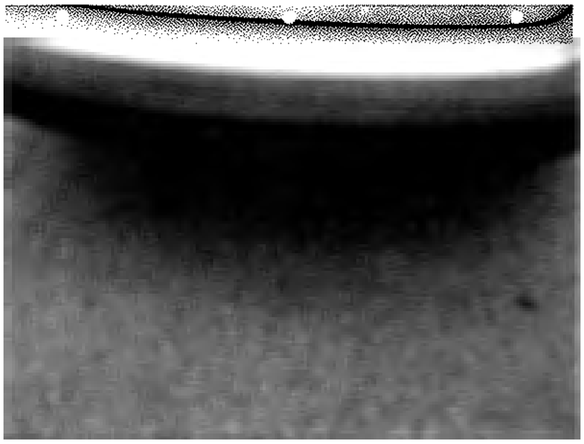

Figure 1: Reproductions of photographs of the subject 2006 Chrysler Pacifica

The reviewed photographs of the incident Honda Civic depicted damage skewed toward the left front corner as indicated by the left fender, left front bumper cover and turn signal lamp deformation. Ms. Marie Ronkar testified the incident Honda damage consisted of the headlight being broken. Further, within Ms. Ronkar's deposition it is indicated there was damage to the front bumper cover, left turn signal, hood, left fender, left fender liner and various other parts on the Honda. Mr. Ronkar testified the incident Honda damage was the *"front left headlight was smashed out"*, *"little bit of a buckle to the hood"*, and a *"little bit of a buckle to the left fender"*. Mr. Quinn testified the *"front left bumper and headlight was cracked"* on the incident Honda.


Figure 2: Reproductions of photographs of the incident 1995 Honda Civic

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Honda can be used to resolve the loads sustained by the subject Chrysler. That is, the loads sustained by the incident Honda are equal and opposite to those of the subject Chrysler. Energy-based crush analyses along with the conservation of linear momentum have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17,18,19,20] Analyses of the photographs and geometric measurements along with the repair record of the incident 1995 Honda Civic revealed the damage due to the subject incident. An energy crush analysis[21] indicates that a single 10 mile-per-hour angled barrier impact to the left front of a Honda Civic would result in significant and visibly noticeable crush across the entirety of the subject Honda's left front structures, with a residual crush of 9.75 inches. This depth of crush would include damage to the left fender, left turn lamp, left headlamp assembly, hood, grille, and front bumper structures. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[22] The lack of significant structural crush to the entire front of the incident Honda Civic along with the conservation of momentum indicates that the subject incident is

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13 Meriam, J.L., (1952). Mechanics Part II: Dynamics. John Wiley & Sons, New York.

14 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995). *Data and Methods for Estimating the Severity of Minor Impacts.* (No. 950352). SAE Technical Paper.

15 Happer, A.J., Hughes, M.C., Peck, M.D., et al. (2003) *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems.* (No. 2003-01-0492). SAE Technical Paper.

16 Campbell, K.L. (1974). *Energy Basis for Collision Severity.* (No. 740565). SAE Technical Paper.

17 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment.* (No. 960891). SAE Technical Paper.

18 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3.* (No. 850253). SAE Technical Paper.

19 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions.* (No. 890740). SAE Technical Paper.

20 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V.* (No. 870045). SAE Technical Paper.

21 EDCRASH, Engineering Dynamics Corp.

22 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

consistent with a collision resulting in a Delta-V below 6 miles per hour for the subject Chrysler Pacifica.

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V significantly below 6 miles-per-hour for the subject Chrysler Pacifica. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6 mile-per-hour impact is 1.8g.[23,24,25,26] By the laws of physics, the average acceleration experienced by the subject Chrysler Pacifica in which Mr. Quinn was seated was less than 1.8g.

The acceleration experienced due to gravity is 1g, which means that Mr. Quinn experiences 1g of loading while in a sedentary state. Therefore, Mr. Quinn experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[27] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

According to his testimony, Mr. Quinn was looking left toward the menu board at the time of the impact. He further specified that his neck and torso were slightly turned leftward. He continued to describe that his right foot was on the brake and he was unaware of the impending collision. The laws of physics dictate that when contact occurred to the rear of the subject Chrysler Pacifica, the vehicle would have been pushed forward causing Mr. Quinn's seat to move forward relative to his body. This rearward motion would result in Mr. Quinn moving rearward relative to the interior of the subject vehicle and his body, specifically his entire torso and pelvis, would load into the seatback structures. Any rebound would have been within the range of protection afforded by the available restraint system. Mr. Quinn testified he was wearing the available three point restraint at the time of the incident. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Quinn would have been limited to well within the range of normal physiological limits.

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23 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

24 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

25 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

26 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

27 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Quinn was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[28,29]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

Mr. Quinn was diagnosed with a cervical, thoracic, and lumbar sprain/strain. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Chrysler Pacifica would be pushed forward and Mr. Quinn would have moved rearward relative to the vehicle, until his motion was stopped by the seatback and seat bottom. Examination of an exemplar 2005 Chrysler Pacifica, production model years 2004-2008, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 32.0 inches in the full-down position and 34.0 inches in the full-up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Mr. Quinn's testimony and medical records indicated he was 74 inches tall, approximately 190 to 214 lbs. and 33 years old at the time of the subject incident. Performing an anthropometric regression of Mr. Quinn revealed he would have a normal seated height of 36.2 to 36.4 inches. Additionally, Mr. Quinn testified his headrest was adjusted properly. Thus, the seatback and headrest would have

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28 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

29 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

provided Mr. Quinn's head and cervical spine with support and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. Furthermore, any forces applied due to interaction with the head restraint would have been applied perpendicular to the cervical spine, thereby limiting compressive loading.

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[30,31,32,33,34] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[35] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [36,37,38,39] Mr. Quinn testified he worked as a grocery store produce clerk. He also testified he would play with his children and golf. Mr. Quinn's medical records further indicated that he exercise regularly each week. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[40]

Mr. Quinn was noted to be looking to the left at the time of the subject incident. This position places Mr. Quinn in an orientation such that there would be less motion of his body and less

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30 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

31 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

32 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

33 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

34 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

35 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

36 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

37 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

38 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

39 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

40 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living.* (No. 2006-01-0247). SAE Technical Paper.

muscle contraction.[41] In other words, there would be less stress and strain placed upon his cervical spine in this orientation.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Quinn cannot be made.

Thoracic and Lumbar Spine

During an event such as the subject incident, the thoracic and lumbar spine of an occupant is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of the thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[42,43,44,45] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[46] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[47,48] Mr.

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41 Kumar, S., Ferrari R., Narayan Y., Kinematic and electromyographic response to whiplash-type impacts. Effect of head rotation and trunk flexion: Summary of research, Clinical Biomechanics 20 (2005) 553-568

42 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

43 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

44 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

45 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

46 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

47 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition.* American Society of Safety Engineers.

48 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

Quinn's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[49,50,51,52,53]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable or greater than those resulting from subject incident. [54,55,56,57] Further studies of activities of daily living measured lumbar accelerations for activities such as sitting, walking, and jumping off a step. These were found to be comparable or greater than the subject incident.[58,59] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[60] Mr. Quinn's medical records indicated that his job required him to lift 45 lb. boxes all day and that he exercised regularly each week. A segmental analysis of Mr. Quinn demonstrated that as he lifted objects during daily tasks, the forces applied to his lumbar spine would have been comparable to or greater than those during the subject incident.[61,62,63]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces

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49 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

50 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

51 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

52 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

53 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

54 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

55 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

56 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

57 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

58 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

59 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

60 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

61 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

62 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

63 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

that exceeded the personal tolerance limits of Mr. Quinn, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Mr. Quinn worked as a produce clerk at the grocery store. Mr. Quinn was capable of playing with his children, golfing, and lifting boxes of up to 45 lbs. Further, he now works in a shipyard performing general maintenance cleaning, washing, and pumping water tanks on boats. These activities can produce greater movement, or stretch, to the soft tissues of Mr. Quinn and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[64]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Quinn's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Quinn using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 6, 2010, Mr. Dennis Quinn was the seat-belted driver of a 2006 Chrysler Pacifica traveling through an Arby's Restaurant drive-thru in Bremerton, Washington when the subject Chrysler was contacted in the rear at a low speed by a 1995 Honda Civic.
2. The severity of the subject incident was consistent with 6 miles-per-hour with an average acceleration less than 1.8g.
3. The acceleration experienced by Mr. Quinn was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Quinn's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

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64 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes).* (No. 960654). SAE Technical Paper.

5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Quinn's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Quinn's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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March 30, 2015

[redacted]

[redacted]

Dear [redacted]:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of [redacted]. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on June 16, 2011, [redacted] was the seat-belted driver of a 1991 Honda Civic preparing to turn left onto Sleater Kinney Road NE in Lacey, Washington. [redacted] was the driver of a model year 1984-1988 Toyota Pickup traveling directly behind the Honda. The available documents indicated that as the Honda was stopped for a red traffic light, contact occurred between the front of the Toyota and the rear of the Honda.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Twenty-two (22) color photographic reproductions of the subject 1991 Honda Civic
- Five (5) color photographic reproductions of the incident 1984-1988 Toyota Pickup
- Deposition Transcript of Aubrey Perschon, [redacted] *vs.* [redacted] [October 7, 2014]
- Medical Records pertaining to [redacted]
- VinLink data sheet for the subject 1991 Honda Civic
- Expert AutoStats data sheets for a 1991 Honda Civic
- Expert AutoStats data sheets for a 1984-1988 Toyota Pickup
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that [redacted] claims were caused by the subject incident on June 16, 2011;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1991 Honda Civic;
3. Determine [redacted] kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate [redacted] personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The medical records and other available documents indicate [redacted] attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic, Lumbar, and Sacroiliac Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions of the subject 1991 Honda Civic and the incident 1984-1988 Toyota Pickup in association with accepted scientific methodologies. [11,12]

The reviewed photographs of the subject Honda depicted slight misalignment of the trunk lid, many scratches to the rear bumper cover, and denting to the rear license plate (Figure 1). The photographs depicted no significant misalignment or crush to the rear structures of the vehicle. [redacted] testified that the Honda's rear bumper *"looked a little but different in positioning, but not—not very much"* and that the license plate was dented. Further, [redacted] testified that the sun visor within the vehicle came out of the ceiling due to the impact.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 1991 Honda Civic

The reviewed photographs of the incident Toyota depicted damage consisting of a bent front license plate. Specifically, the license plate was bent along its horizontal axis and there was no significant crush to the front bumper structures of the incident Toyota (Figure 2). [redacted] testified that she could not recall any damage that she remembered seeing on the incident Toyota.

Figure 2: Reproductions of photographs of the incident 1984-1988 Toyota Pickup

Analyses of the photographs and geometric measurements of the subject 1991 Honda Civic revealed the damage due to the subject incident. An energy crush analysis[13] indicates that a single 10 mile-per-hour angled barrier impact to the rear of a Honda Civic would result in significant and visibly noticeable crush across the entirety of the subject Honda's rear structures, with a residual crush of 5.5 inches. This depth of crush would include damage to the trunk lid, rear tail lights, rear body panel, and rear bumper structures. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[14] The lack of significant structural crush to the entire rear of the incident Honda Civic indicates that the subject incident is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour for the subject Honda Civic.

Further, it is important to note the top of the front bumper of the incident Toyota is 32 inches from the ground, while the rear bumper of the subject Honda is 23 inches from the ground. Analyzing the photographs and utilizing the geometric measurements along with photogrammetry indicates the portion of the incident Toyota that contacted the subject Honda was the lower half of the license plate and below. [15,16] Had there been any significant crush to the underlying structures of the subject Honda's rear bumper structures the subject incident would have resulted in an override scenario as the upper portion of the incident Toyota would have contacted the trunk lid area of the subject Honda. The lack of an override scenario further supports the above analysis.

Furthermore, the IIHS tested multiple vehicles of the same era from the same manufacturer as the subject vehicle, as well as vehicles from other manufacturers. In a 5 mile-per-hour rear impact into a barrier, the test vehicles sustained damage comparable if not greater to the damage sustained on the subject Honda. The primary damage to the subject Honda was only cosmetic in

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13 EDCRASH, Engineering Dynamics Corp.

14 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

15 ImageJ 1.47v, National Institute of Health, USA, http://imagej.nih.gov/ij.

16 Randles, B., et. al. (2010). *The Accuracy of Photogrammetry vs. hands-on Measurement Techniques used in Accident Reconstruction*. (No. 2010-01-0065). SAE Technical Paper.

nature. Thus, because the test vehicles in the IIHS rear impact tests sustained comparable damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles per hour.

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V significantly below 10 miles-per-hour for the subject Honda Civic and consistent with 5 miles-per-hour. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g and 1.5g for 5 miles-per-hour.[17,18,19,20] By the laws of physics, the average acceleration experienced by the subject Honda in which [redacted] was seated was less than 3.0g and consistent with 1.5g.

The acceleration experienced due to gravity is 1g, which means that [redacted] experiences 1g of loading while in a sedentary state. Therefore, [redacted] experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[21] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

According to the medical records and [redacted] testimony, she was 66-67 inches tall, weighed approximately 201 lbs., and was 18 years old at the time of the incident. The records and testimony described she was looking straight ahead and unaware of the impending collision. The records and testimony further described that her body was *"flung"* forward and back due to the collision.

The above described body motion is contrary to the actual motions during the subject incident. The laws of physics dictate that when contact occurred to the rear of the subject Honda Civic, the vehicle would have been pushed forward causing [redacted] seat to move forward relative to her body. This rearward motion would result in [redacted] moving rearward relative to the interior of the subject vehicle and her body, specifically her entire torso and pelvis, would load into the seatback structures. Any rebound would have been within the range of protection afforded by the available restraint system. The medical records reported [redacted] was wearing the available three point restraint at the time of the incident. The restraint provided by the seatback and seat

17 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

18 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

19 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

20 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

21 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

belt system were such that any motion of [redacted] would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to [redacted] was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

[redacted] was diagnosed with a cervical, thoracic, lumbar, and sacroiliac sprain/strain. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda Civic would be pushed forward and [redacted] would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 1989 Honda Civic, production model years 1988-1991, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 29.0 inches in the full-down position and 31.5 inches in the full-up position. Note, the photographs of the subject Honda Civic depict the driver's headrest in the up position. Furthermore, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of [redacted] revealed she would have a normal seated height of 33.8

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22 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

23 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

to 34.2 inches. The medical records reported [redacted] head contacted the headrest due to the incident. Thus, the seatback and headrest would have provided [redacted] head and cervical spine with support and one would not expect to see any biomechanical failures greater than transient neck stiffness and soreness. Any forces applied due to interaction with the headrest would have been applied perpendicular to the cervical spine, thereby limiting compressive loading.

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[24,25,26,27,28] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[29] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

[redacted] testified she had just graduated from high school and while in high school she participated in physical education class which included soccer, volleyball, golf, and other sports. She testified that she enjoyed cooking, swing dancing, exercising, and helping her brother repair automobiles. The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.

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24 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

25 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

26 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

27 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

28 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

29 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

[30,31,32,33] Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[34]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of [redacted] cannot be made.

Thoracic, Lumbar, and Sacroiliac Spine

During an event such as the subject incident, the thoracic, lumbar, and sacroiliac spine of an occupant is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of the thoracic, lumbar, and sacroiliac spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic, lumbar, and sacroiliac spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic, lumbar, and sacroiliac spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[35,36,37,38] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[39] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured

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30 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

31 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

32 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

33 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

34 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

35 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

36 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

37 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

39 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

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spinal response to rear impact accelerations at severities greater than the subject incident.[40,41] [redacted] thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[42,43,44,45,46]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable or greater than those resulting from the subject incident. [47,48,49,50] Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable or greater than the subject incident.[51,52] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[53] [redacted] testified she enjoyed running 2-3 miles up to 5 days per week. She continued to testify she enjoyed swing dancing and was capable of performing many other daily activities. A segmental analysis of [redacted] demonstrated that as she lifted objects during daily tasks, the forces applied to her lumbar spine would have been comparable to or greater than those during the subject incident.[54,55,56]

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40 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

41 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

42 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

43 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

44 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

45 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

46 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

47 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

48 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

49 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

50 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

51 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

52 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

53 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

54 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

55 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

56 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic, lumbar, and sacroiliac spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic, lumbar, and sacroiliac spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of [redacted] a causal link between the subject incident and claimed thoracic, lumbar, and sacroiliac biomechanical failures cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents, [redacted] participated in several recreational activities and daily activities. After the incident, she testified she started a cleaning business and is capable of cleaning bath tubs, toilets, dishes, and laundry among other activities. These activities can produce greater movement, or stretch, to the soft tissues of [redacted] and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[57]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between [redacted] reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of [redacted] using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On June 16, 2011, [redacted] was the seat-belted driver of a 1991 Honda Civic that was contacted in the rear at a low speed by a 1984-1988 Toyota Pickup.
2. The severity of the subject incident was significantly below 10 miles-per-hour, consistent with 5 miles-per-hour, with an average acceleration less than 3.0g and consistent with 1.5g.
3. The acceleration experienced by [redacted] was within the limits of human tolerance and comparable to that experienced during various daily activities.

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57 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper.

4. The forces applied to the subject vehicle during the subject incident would tend to move [redacted] body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed thoracic, lumbar and sacroiliac biomechanical failures. As such, a causal relationship between the subject incident and the thoracic, lumbar and sacroiliac biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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April 1, 2015

Alina Polyak, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 Second Avenue
Suite 500
Seattle, WA 98101

Re: *Miller, Mervis v. Elinor Paulus*
ARCCA Case No.: 3271-273
Your Claim No.: 3606 7142 5048

Dear Ms. Polyak:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and kinematics experienced by Mervis Miller. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available and the claimed biomechanical failures of the vehicle occupants, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of both the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from

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1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the reviewed documents, on March 20, 2013 Mervis Miller, driver of a 2010 Dodge Charger, was stopped for traffic on Interstate 5 in Seattle, Washington. Martha Johnson was the driver of 1996 Saab 9000 CS travelling directly behind the subject Dodge Charger. Elinor Paulus was the driver of a 1998 Subaru Legacy directly behind the incident Saab. Ms. Paulus failed to stop her vehicle in time. As a result, the front of the incident Subaru contacted the rear of the incident Saab. The Saab subsequently moved forward and the front of the incident Saab contacted the rear of the subject Dodge.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Complaint For Personal Injuries In Tort
- Summons
- Three (3) color digital reproductions of photographs of the subject Dodge Charger
- Two (2) color digital reproductions of photographs of the incident Saab 9000 CS
- Deposition transcript of Mervis Miller, February 25, 2015
- Gerber Collision & Glass - Woodinville Estimate of Record for the subject Dodge Charger, written by Gordy Dorning, March 26, 2013
- Thoroughbred Collision Center – West Sea Estimate of Record for the incident Saab 9000 CS, written by Chris Williams, March 26, 2015
- VinPower and Expert AutoStats data sheets for the subject Dodge Charger
- VinPower and Expert AutoStats data sheets for the incident Sab 9000 CS

Damage and Incident Severity:

The photographs and repair estimates for the Dodge Charger and Saab 9000 CS were utilized in analyzing the incident severity. There was cosmetic damage to the subject Dodge and incident Saab.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Saab can be used to resolve the loads sustained by the subject Dodge. That is, the loads sustained by the incident Saab are equal and opposite to those of the subject Dodge. Energy-based crush analyses along with the conservation of linear momentum have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[4,5,6,7,8,9,10,11] Analyses

4 Meriam, J.L., (1952). Mechanics Part II: Dynamics. John Wiley & Sons, New York.

5 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995). *Data and Methods for Estimating the Severity of Minor Impacts*. (No. 950352). SAE Technical Paper.

6 Happer, A.J., Hughes, M.C., Peck, M.D., et al. (2003) *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

7 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

of the photographs and geometric measurements along with the repair record of the incident 1996 Saab 9000 CS revealed the damage due to the subject incident. An energy crush analysis[12] indicates that a single 10 mile per hour flat barrier impact to the rear of a Saab 9000 CS would result in significant and visibly noticeable crush across the entirety of the subject Saab's rear structure, with a residual crush of 5.25 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[13] The lack of significant structural crush to the entire rear of the incident Saab is consistent with a collision resulting in a Delta-V significantly below 10 miles per hour for the incident Saab 9000 CS.

The 10 mile-per-hour Delta-V to the rear of the incident Saab indicates that Saab would move forward at a maximum of ten miles-per-hour from a complete stop prior to contacting the rear of the subject Dodge. A conservation of momentum analysis indicates that for a 10 mile-per-hour closing velocity impact between the front of the incident Saab and the rear of the subject Dodge, the subject Dodge would experience a maximum 5.3 mile-per-hour Delta-V

Review of the vehicle damage, incident data, published literature, engineering analyses, and my experience indicates an incident resulting in a Delta-V of 5.3 miles-per-hour for the subject Dodge Charger. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the peak acceleration associated with a 5.3 mile-per-hour impact is 3.2g.[14] By the laws of physics, the peak acceleration experienced by the subject Dodge in which Mr. Miller was seated was less than to 3.2g.

Kinematic Analysis:

According to the laws of physics, when contact between the Saab and the Dodge occurred, had there been enough energy transferred to cause any motion, the Dodge would have been accelerated and pushed forward. This would have resulted in the vehicle moving forward relative to Mervis Miller, causing his body to load into the seat and seat back, thus coupling his motion to the vehicle. One would not expect hyperextension of the head and neck in the subject incident. Szabo et al.,[15] McConnell et al.,[16] and West et al.[17] have shown that hyperextension does not occur at energy levels such as those that were experienced in the subject incident. Finally, the low accelerations resulting from this collision would have caused little, or no, forward rebound of his

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8 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

9 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

10 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

11 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

12 EDCRASH, Engineering Dynamics Corp.

13 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

14 Agaram, V., et al (2000). "Comparison of frontal crashes in terms of average acceleration" (SAE 2000010880) Warrendale, PA. Society of Automotive Engineers.

15 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

16 McConnell WE, Howard RP, Guzman HM, Bomar JB, Raddin JH, Benedict JV, Smith HL, and Hatsell CP (1993). *Analysis of Human Test subject Kinematic Responses to Low Velocity Rear End Impacts* (SAE 930889). Warrendale, PA: SAE.

17 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

body away from the seat back.[18,19,20] Any rebound would have been within the range of protection afforded by the available restraint system.

Mr. Miller was noted to be looking to the right at the time of the subject incident. This position places Mr. Miller in an orientation such that there would be less motion of his body and less muscle activation.[21] In other words, there would be less stress and strain placed upon his cervical spine in this orientation.

<u>Discussion</u>:

The acceleration experienced due to gravity is 1g. This means that Mr. Miller experiences 1g of loading while in a sedentary state. Therefore, he experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by him in his daily life would have increased the loading to his body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[22] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the maximum 1g associated with the subject incident.[23]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to the occupant of the subject Dodge Charger was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism in the subject incident.

Research by Funk et al.[24] demonstrated that a simple head shake or a self-inflicted hand strike to the head induces accelerations comparable to or greater than the subject incident. Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mervis Miller in the subject Dodge was well

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18 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

19 Comments to Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

20 Tencer, A. F., S. Mirza, et al. (2004). "A Comparison of Injury Criteria Used in Evaluating Seats for Whiplash Protection." <u>Traffic Injury Protection</u> **5**(1): 55-66.

21 Kumar, S., Ferrari R., Narayan Y., Kinematic and electromyographic response to whiplash-type impacts. Effect of head rotation and trunk flexion: Summary of research, Clinical Biomechanics 20 (2005) 553-568

22 Mow, V. C. and W. C. Hayes (1991). <u>Basic Orthopaedic Biomechanics</u>. New York, Raven Press.

23 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

24 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident.

In recent papers by Ng et al.,[25,26] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. In the article, the authors concluded that peak accelerations were observed to be similar for different groups (by size and gender). As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On March 20, 2013, Mr. Miller was the driver of the subject Dodge Charger which was contacted on the rear by a Saab 9000 CS at low speed.
2. The severity of the subject incident is consistent with a Delta-V of a maximum 5.3 miles-per-hour, with a maximum acceleration of 3.2g for the subject Dodge Charger in which Mr. Miller was seated.
3. Mr. Miller would move toward the rear, relative to the interior during the subject incident, this motion would be supported by his seat back.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist
BWP/cdr

[25] Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

[26] Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

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April 22, 2015

Eric J. Waxler, Esquire
Hiefield, Foster & Glascock LLP
6915 SW Macadam Avenue
Suite 300
Portland, OR 97219

Re: *Hossein, Elisha v. Kelly Klingele*
File No.: 116-635
ARCCA Case No.: 3666-049

Dear Mr. Waxler:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Elisha Hossein. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the Complaint and other available documents, on October 30, 2013, Ms. Elisha Hossein was the seat belted driver of a 2007 Mercedes-Benz westbound on Cornell Road preparing to turn right onto NW 173rd Avenue in Beaverton, Oregon. Mr. Scott McCoy was the driver of a 2002 Subaru Impreza traveling directly behind the Mercedes-Benz. According to the available documents, the Subaru was struck from behind by another vehicle and pushed forward into the rear of the subject Mercedes-Benz as it was moving. As a result, contact occurred between the front of the incident Subaru and rear of the subject Mercedes-Benz. No airbags were deployed in the subject Mercedes-Benz or the incident Subaru as a result of the subject incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Twenty-five (25) color photographic reproductions of the subject 2007 Mercedes-Benz ML350
- Twelve (12) color photographic reproductions of the incident 2002 Subaru Impreza
- Progressive Universal Insurance Repair Estimate for the subject 2007 Mercedes-Benz ML350 [November 22, 2013]
- Progressive Universal Insurance Repair Estimate for the subject 2007 Mercedes-Benz ML350 [December 12, 2013]
- State Farm Insurance Companies Repair Estimate for the incident 2002 Subaru Impreza [November 6, 2013]
- Complaint, *Elisha Hossein vs. Kelly Klingele* [November 12, 2014]
- Deposition Transcript of Elisha Hossein, *Elisha Hossein vs. Kelly Klingele* [February 12, 2015]
- Deposition Transcript of Kelly Klingele, *Elisha Hossein vs. Kelly Klingele* [February 12, 2015]
- Medical Records pertaining to Elisha Hossein
- VinLink data sheet for the subject 2007 Mercedes-Benz ML350
- Expert AutoStats data sheets for a 2007 Mercedes-Benz ML350
- VinLink data sheet for the incident 2002 Subaru Impreza
- Expert AutoStats data sheets for a 2002 Subaru Impreza
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Hossein claims were caused by the subject incident on October 30, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2007 Mercedes-Benz ML350;
3. Determine Ms. Hossein's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Hossein's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The Complaint, medical records and other available documents indicate Ms. Hossein attributes the following biomechanical failures as a result of the subject incident:

- Concussion
- Cervical Spine
    - Sprain/strain
    - Aggravation of pre-existing conditions
- Thoracic, Lumbar and Sacroiliac Spine
    - Sprain/strain
    - Aggravation of pre-existing conditions
- Bilateral Shoulder
    - Sprain/strain

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

    - Aggravation of pre-existing conditions
- Left Knee
    - Medial meniscus posterior horn tear

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2007 Mercedes-Benz ML350 and incident 2002 Subaru Impreza in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject Mercedes-Benz reported damage primarily to the rear engine under cover, right rear exhaust muffler pipe, right exhaust tail pipe tip, right rear exhaust bracket, right rear exhaust hanger, right rear exhaust heat shield, left and right lower quarter panel, liftgate shell, rear body gate opening panel, center rear body panel, rear body floor pan, rear bumper trailer hitch, rear upper bumper cover, rear lower bumper cover, rear bumper retaining strip, and rear bumper flap; which is consistent with the reviewed photographs (Figure 1). The photographs depicted damage consisting of broken rear bumper cover components and primarily to undercarriage components. Further, the photographs depicted no visible crush to the rear liftgate, tail lights or quarter panels of the subject Mercedes-Benz.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

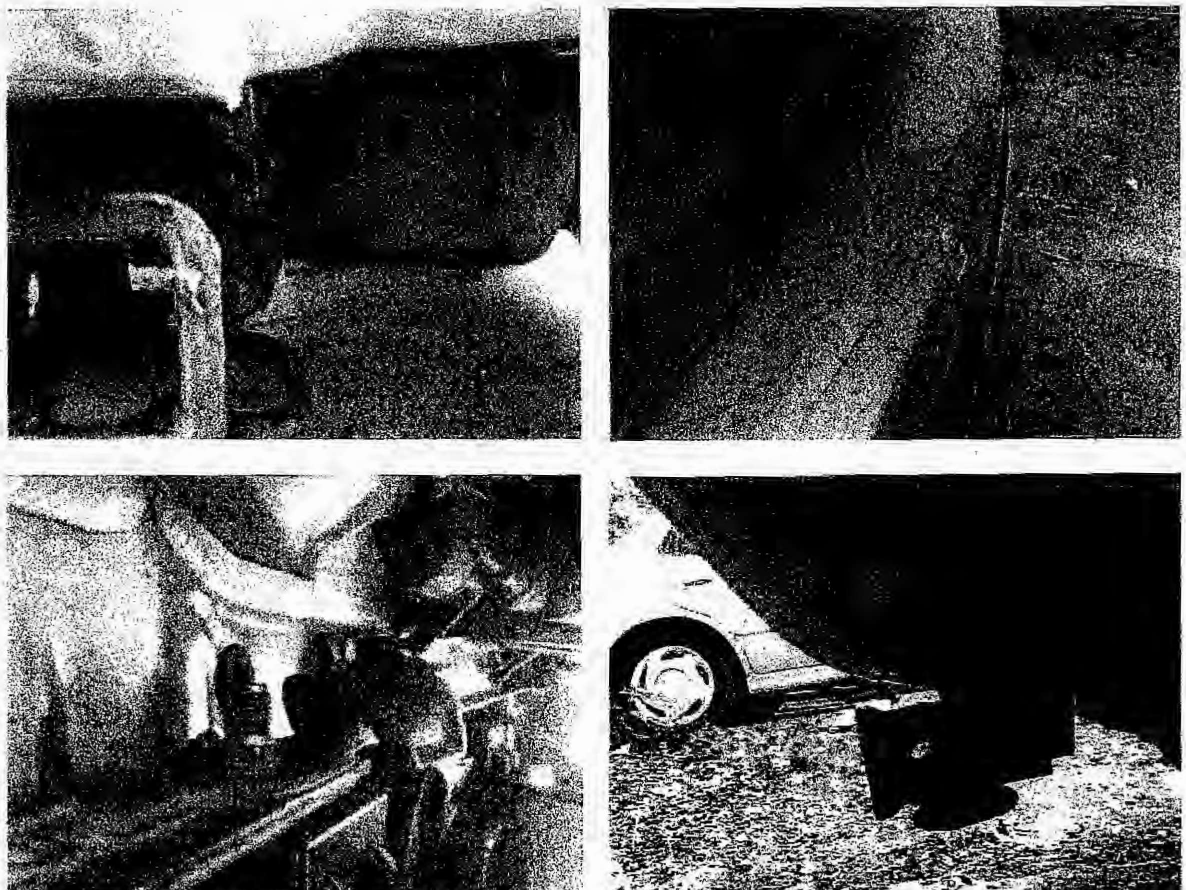

Figure 1: Reproduction of the subject 2007 Mercedes-Benz ML350

The repair estimate for the incident Subaru indicated there was damage primarily to the left quarter panel, left rear frame rail, left inner quarter panel, left rear quarter panel pan, tailgate assembly, rear bumper assembly, muffler assembly, rear body panel, rear floor pan, left tail lamp assembly, and the left front half body section; which is consistent with the available photographs. Additionally, the Subaru required a 4 wheel alignment and a unibody/frame setup. The photographs depicted considerable crush damage to the rear of the incident Subaru (Figure 2). Further, the photographs depicted crush damage to the left front, primarily above the front bumper structure.

Figure 2: Reproduction of the incident 2002 Subaru Impreza

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions. [13,14,15,16,17] Analyses of the photographs with confirmation by the repair estimate and geometric measurements of the subject 2007 Mercedes-Benz ML350 revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 mile per hour impact to the rear of a Mercedes-Benz ML350 would result in significant and visibly noticeable crush across the entire rear of the subject Mercedes-Benz, with a residual crush of 4.25 inches. A crush of this depth would result in the entire rear bumper structure being pushed forward into the rear body panel 4.25 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural crush to the entire rear of the subject Mercedes-Benz indicates that the subject incident is consistent with a collision resulting in a Delta-V below 10 miles per hour.

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V below 10 miles-per-hour for the subject 2007 Mercedes-Benz ML350. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[20,21,22,23] By the laws of physics, the average acceleration experienced by the subject Mercedes-Benz in which Ms. Hossein was seated was less than 3.0g.

The acceleration experienced due to gravity is 1g. This means that Ms. Hossein experiences 1g of loading while in a sedentary state. Therefore, Ms. Hossein experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [24] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

20 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

21 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

22 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

23 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

24 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Kinematic Analysis:

The medical records reported Ms. Hossein with 46 years of age, 69 inches in height and weighed approximately 155 pounds at the time of the subject incident. Ms. Hossein testified she was seated with her right foot on the brake and her left foot on the floor. She continued to describe that her hands were on the steering wheel. Due to the impact Ms. Hossein testified her body moved forward then backward and that she contacted her left knee on the steering wheel or dashboard. In addition, Ms. Hossein testified her head struck the headrest.

Ms. Hossein's described motion is contrary to the laws of physics. The laws of physics dictate that when the subject Mercedes-Benz was contacted in the rear, it would have been pushed forward causing Ms. Hossein's seat to move forward relative to her body. This motion would result in Ms. Hossein moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Hossein's torso and pelvis would settle back into the seatback and seat bottom cushions. Any rebound would have been within the range of protection afforded by the available restraint system. The available documents indicated Ms. Hossein was wearing the available three point restraint. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Hossein would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Hossein was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[25,26]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

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25 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

26 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck.* (No. 710855). SAE Technical Paper.

Concussion

A brain biomechanical failure without skull fracture is classified as a mild diffuse brain biomechanical failure or concussion.[27,28] Acute onset of concussion requires that the brain tissue be stretched and/or strained beyond physiological limits.[29,30,31,32] The biomechanical failure mechanism required to cause a concussion is loading to the brain that causes stretching and/or straining of the brain tissue beyond physiological limits. These biomechanical failures are associated with substantial impulsive or impact loads applied to the head.[33] The Head Injury Criterion (HIC) has been adopted by the United States federal government as the standard criterion for the determination of risk of a head biomechanical failure for the Federal Motor Vehicle Safety Standards (FMVSS). In brief, HIC is calculated from resultant accelerations at the center of gravity of the head (based upon three orthogonal directions) that are optimized over the duration of an impact.

The subject incident lacked the energy necessary to cause Ms. Hossein's claimed concussion.[34,35] The medical records indicated Ms. Hossein did not experience a loss of consciousness. As described previously, her body would have moved rearward relative to the Mercedes-Benz's interior. The seatback structures would have supported and limited her body motion. During this response, Ms. Hossein's head would have been subjected to some degree of rearward extension upon impact and potential head contact with the headrest. Ms. Hossein testified that her head did in fact contact the headrest due to the impact. However, this head contact would not have generated enough energy to cause biomechanical failure or trauma to the head.[36] Additionally, had there been enough energy for rebound of Ms. Hossein's body the seat belt retractors would have locked when accelerations exceed 0.7g, thereby limiting her forward motion to well within physiological limits.[37]

This subject incident had an average acceleration less than 3.0g. Ms. Hossein testified she was capable of performing normal daily activities. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[38,39] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were

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27 Gennarelli, T.A., (1982) "Impact Injury Caused by Linear Acceleration: Mechanisms, Prevention, and Cost." NATO AGARD Conference 1-9.

28 Viano, D.C. Biomechanics of Head Injury – Toward a Theory Linking Head Dynamic Motion, Brain Tissue Deformation and Neural Trauma, (SAE 881708). Warrendale, PA. Society of Automotive Engineers.

29 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

30 Gennarelli, T.A., (2003) "Mechanisms of Brain Injury." *Journal of Emergency Medicine,* 11: 5-11.

31 Yoganandan, N., Gennarelli, T.A., et al., (2009) "Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes." *Journal of Trauma,* 66(2): 309-315.

32 Mclean, A.J., (1995) "Brain Injury without Head Impact?" *Journal of Neurotrauma,* 12(4): 621-625.

33 Goldsmith, W., (2001) "The State of Head Injury Biomechanics: Past, Present, and Future: Part 1." Critical Reviews in Biomedical Engineering 29 (5 & 6): 441-600.

34 Yoganandan, N., Gennarelli, T.A., et al., (2009) "Association of Contact Loading in Diffuse Axonal Injuries from Motor Vehicle Crashes." *Journal of Trauma,* 66(2): 309-315.

35 Mclean, A.J., (1995) "Brain Injury without Head Impact?" *Journal of Neurotrauma,* 12(4): 621-625.

36 West, D.H., J.P. Gough, et al., (1993) "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

37 Federal Motor Vehicle Safety Standard 209: Seat Belt Assemblies, 49 CFR 571.209.

38 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

39 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g.

Based upon the review of the available incident data and the results cited in the technical literature, the subject incident created accelerations that were well within human tolerance and were comparable to accelerations applied during daily activities. Therefore, the subject incident was within Ms. Hossein's personal tolerance. In addition, the loads associated with the subject incident were not applied in the proper manner or with sufficient magnitude to generate the biomechanical failure mechanism necessary for her concussion. As this crash event did not apply loads of sufficient magnitude to exceed Ms. Hossein's personal tolerance and the necessary biomechanical failure mechanism was not created, causation between the subject incident and her concussion cannot be established.

Cervical Spine

According to the available documents, Ms. Hossein was diagnosed with a cervical sprain/strain. In addition, the documents indicated Ms. Hossein had prior cervical conditions including undergoing a prior cervical MRI dated January 16, 2013.

A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[40] In the absence of this acute biomechanical failure mechanism for cervical disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[41,42]

In a rear impact that produces motion of the subject vehicle, the Mercedes ML350 would be pushed forward and Ms. Hossein would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2006 Mercedes ML500, essentially the same vehicle as the 2007 Mercedes ML350, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 32.0 inches in the full-down position and 34.5 inches in the full-up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Hossein revealed he would have a normal seated height of 4.6 inches. Thus, the seatback and headrest

40 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

41 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

42 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

support and the low vehicle accelerations during the subject incident designate that Ms. Hossein's cervical spine would have undergone only a subtle degree of the characteristic response phases.[43]

The National Highway Traffic Safety Administration (NHTSA) impact safety tests for continued performance and safety monitoring of the automotive industry. Tests for a 2006 and 2007 Mercedes-Benz ML350 showed the seated height of a 50th percentile male in the driver's seat was well protected and supported by the head restraint (Figure 3).[44,45]

Figure 3: NTHSA 50th Percentile Male Seated Position

Ms. Hossein had a normal seated height of 34.6 inches, nearly identical to a 50th percentile male. Of note, Ms. Hossein testified that her head struck the headrest. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Hossein's cervical spine would have undergone only a subtle degree of the characteristic response phases.[46] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[47] The cervical loads were within physiologic limits and Ms. Hossein would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[48,49,50]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[51,52,53,54,55] The test subjects

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43 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

44 National Highway Traffic Safety Administration (2007). New Car Assessment Program Side Impact Test, Report No. SNCAP-CAL-07-04. 2007 Mercedes-Benz ML350.

45 National Highway Traffic Safety Administration (2005). New Car Assessment Program Side Impact Test, Report No. SNCAP-CAL-06-01. 2006 Mercedes-Benz ML350.

46 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

47 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

48 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

49 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

50 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

51 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

52 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[56] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [57,58,59,60] The available documents reported Ms. Hossein was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[61]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Hossein cannot be made.

Thoracic, Lumbar and Sacroiliac Spine

According to the available documents, Ms. Hossein was diagnosed with a thoracic, lumbar and sacroiliac sprain/strain. In addition, the documents indicated Ms. Hossein had prior back conditions including undergoing a prior lumbar MRI dated January 30, 2011.

During an event such as the subject incident, the thoracic, lumbar and sacroiliac spine of an occupant is well supported by the seat and seatback. This support prevents biomechanical failure motions or

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53 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

54 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

55 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

56 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

57 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

58 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

59 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

60 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

61 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

loading of the thoracic, lumbar and sacroiliac spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic, lumbar and sacroiliac spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic, lumbar and sacroiliac spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur. A sprain is an injury which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is an injury to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type injury to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[62] In the absence of this acute biomechanical failure mechanism for lumbar disc failure, scientific investigations have shown that the above lumbar disc diagnoses can be the result of the normal aging process.[63,64]

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[65,66,67,68] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[69] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[70,71] Ms. Hossein's thoracic, lumbar and

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62 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

63 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

64 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

65 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

66 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

67 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

68 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

69 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

70 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

sacroiliac spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[72,73,74,75,76]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable or greater than those resulting from subject incident. [77,78,79,80] Further studies lumbar accelerations during activities of daily living and found accelerations for activities such as sitting, walking, and jumping off a step to be comparable or greater than the subject incident.[81,82] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[83] According to the available documents, Ms. Hossein was capable of performing daily activities. A segmental analysis of Ms. Hossein demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[84,85,86]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic, lumbar and sacroiliac spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic, lumbar and sacroiliac spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that

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71 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

72 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

73 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

74 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

75 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

76 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

77 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

78 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

79 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

80 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

81 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

82 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

83 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

84 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

85 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

86 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

exceeded the personal tolerance limits of Ms. Hossein, a causal link between the subject incident and claimed thoracic, lumbar and sacroiliac biomechanical failures cannot be made.

Bilateral Shoulder

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The acromioclavicular (AC) joint is formed by the lateral end of the clavicle and the medial end of the acromion. The joint is stabilized by the coracoclavicular ligaments and AC capsule. An acromioclavicular sprain/strain refers to inflammation and over stretching of these ligaments and soft tissues surrounding the AC joint. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[87,88,89] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

During the subject incident, Ms. Hossein's body and extremities would have moved rearward relative to the subject vehicle's interior.[90,91,92,93] This rearward motion would have been supported by the seatback. Ms. Hossein's upper torso would have loaded into the seat structures and if there was rebound, the seat belt would have engaged Ms. Hossein's bony left clavicle and pelvis, limiting her motion during both subject incident. The direction, force and magnitude of the impact would not be sufficient to cause biomechanical failure.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[94,95,96,97] Ms. Hossein testified she was capable of performing daily activities. These activities would directly load Ms. Hossein's shoulders to comparable or greater loads than the subject incident.

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87 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

88 Melenevsky, Y., Yablon, C.M., Ramappa, A., Hochman, M.G. (2009) "Clavicle and Acromioclavicular Joint Injuries: A Review of Imaging, Treatment, and Complications." Skeletal Radiology. 40:831-842.

89 Simovitch, R., Sanders, B., Ozbaydar, M., Lavery, K., Warner, J.J.P., (2009) "Acromioclavicular Joint Injuries: Diagnosis and Management." J Am Acad Orthop Surg. 4:207-219.

90 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

91 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects.* (No. 2001-01-0168). SAE Technical Paper.

92 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

93 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions.* (No. 2010-01-0067). SAE Technical Paper.

94 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics. 42*(12), 1840-1849.

95 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics, 19*(6), 586-594.

96 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).

97 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics, 40*(10), 2139-2149.

The low accelerations in the subject incident and the restraint provided by the seatback, were such that any motion of Ms. Hossein's shoulders would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported bilateral shoulder biomechanical failures of Ms. Hossein cannot be made.

Left Knee

According to an operative report pertaining to Ms. Hossein's left knee, dated December 19, 2013 there were findings consistent with patellar mild to moderate grade III degenerative changes and extremely mild trochlear degenerative changes. In addition, the report indicated there was a posterior horn medial meniscus tear that exceeded on the inferior surface just barely.

Additionally, Ms. Hossein had a prior left knee operation on February 12, 2011 in which she underwent an osteochondral autograft transfer system (OATS) procedure to repair a cartilage defect on the medial femoral condyle of her left knee.

The medial and lateral menisci are C-shaped fibrocartilaginous structures affixed to the proximal tibial articular surface, whose primary functions are of shock absorbers and allow articulation between the femur and tibia. The typical mechanism for meniscal failure is twisting of the knee when the knee is weight-bearing and flexed.[98] In the absence of the aforementioned acute biomechanical failure mechanisms, scientific literature demonstrates that these injuries are often chronic in nature and associated with the normal aging process.[99,100,101]

As previously discussed, as a result of the subject incident Ms. Hossein would move rearward relative to her vehicle and any forward rebound away from the seatback would have been well-controlled by the available restraint system.[102,103] This motion would result in Ms. Hossein moving away from the subject vehicle floor and pedals.[104] These actions do not create the biomechanical failure mechanisms required for meniscal failure. Neither the mechanism nor the force magnitude associated with the claimed left knee biomechanical failures is created by this event. The loading and kinematics of this area of the body were well within the limits of human tolerance and physiological motion. Even if one were to assume that the contact between Ms. Hossein's left knee and the interior occurred, previous research has shown that this force and resulting motion would have been insufficient to cause meniscal failure.[105,106,107,108,109,110,111,112] In addition, Ms. Hossein would have

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98 Moore K.L. (1985) Clinically Oriented Anatomy, Second Edition, Williams & Wilkins.

99 Aichroth, P. (1996). "Degenerative Meniscal Tears." The Knee / Abstracts 3: 70-71.

100 Englund, M., Guermazi, A., and Lohmander, L.S. (2009). "The Meniscus in Knee Osteoarthritis." Rheum Dis Clin N Am 35: 579-590.

101 Biedert, R.M., and Sanchis-Alfonso, V. (2002). "Sources of Anterior Knee Pain." Clinics in Sports Medicine 21: 335-347.

102 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

103 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

104 Ivory, M.A., Furbish, C., et al., (2010) Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions (SAE 2010-01-0067). Warrendale, PA, Society of Automotive Engineers.

105 Balasubramanian, S., Beillas, P., et al. (2004). Below Knee Impact Responses Using Cadaveric Specimens. *Stapp Car Crash Journal* 48: 71-88.

106 Bartsch, A.J., Bolte IV, J.H. et al. (2006). Application of Anthropomorphic Test Device Crash Test Kinetics to Post Mortem Human Subject Lower Extremity Testing (SAE 2006-01-0251). Warrendale, PA, Society of Automotive Engineers.

107 Meyer, E.G. and Haut, R.C. (2003). The Effect of Impact Angle of Knee Tolerance to Rigid Impacts. *Stapp Car Crash Journal* 47: 1-19.

108 Ewers, B.J., Jayaraman, V.M. et al. (2000). The Effect of Loading Rate on the Degree of Acute Injury and Chronic Conditions in the Knee After Blunt Impact (SAE 2000-01-SC20). Warrendale, PA, Society of Automotive Engineers.

had ample knee space (Figure 4), note Ms. Hossein is nearly identical in size to the 50th percentile male.[113,114]

Figure 4: NTHSA 50th Percentile Male Seated Position

The available documents indicate Ms. Hossein was capable of performing daily activities prior to the subject incident. Daily activities and occurrences such as walking, stumbling, single leg hopping and jumping have been shown to have comparable and greater impact forces on the body.[115,116,117,118,119,120,121,122,123,124,125,126] These actions would apply direct loads to Ms. Hossein's left knee of comparable or greater magnitude than she was exposed to during the subject incident.

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109 Stevens, K.J., and Dragoo, J.L. (2006). Anterior Cruciate Ligament Tears and Associated Injuries. *Top Magn Reson Imaging* 17(5): 347-362.

110 Moore K.L. (1985) Clinically Oriented Anatomy, Second Edition, Williams & Wilkins.

111 Kajzer, J., Schroeder, G. et al. (1997). Shearing and Bending Effects at the Knee Joint at High Speed Lateral Loading (SAE 973326). Warrendale, PA, Society of Automotive Engineers.

112 Jayaraman, V.M., Sevensma, E.T. et al. (2001). Effects of Anterior-Posterior Constraint on Injury Patterns in the Human Knee During Tibial-Femoral Joint Loading from Axial Forces through the Tibia (SAE 2001-22-0021). Warrendale, PA, Society of Automotive Engineers.

113 National Highway Traffic Safety Administration (2007). New Car Assessment Program Side Impact Test, Report No. SNCAP-CAL-07-04. 2007 Mercedes-Benz ML350.

114 National Highway Traffic Safety Administration (2005). New Car Assessment Program Side Impact Test, Report No. SNCAP-CAL-06-01. 2006 Mercedes-Benz ML350.

115 Keller, T.S., et al., (1996) "Relationship between vertical ground reaction force and speed during walking, slow jogging and running." *Clinical Biomechanics,* 11(5): 253-259.

116 Gottschall, J.S., Kram, R., (2005) "Ground reaction forces during downhill and uphill running." *Journal of Biomechanics,* 38: 445-452.

117 Bergmann, G., Graichen, F., Rohlmann, A., (2003) "Hip joint contact forces during stumbling." *Langenbecks Arch Surg,* 389:53-59.

118 Lindenberg, K.M., Garcia, C.R., (2013) "The influence of heel height on vertical ground reaction force during landing tasks in recreationally active and athletic collegiate females." *The International Journal of Sports Physical Therapy,* 8(1): 1-8.

119 Veilleux, L.N., Rauch, F., Lemay, M., Ballaz, L., (2012) "Agreement between vertical ground reaction force and ground reaction force vector in five common clinical tests." *J Musculoskeletal Neuronal Interact,* 12(4):219-223.

120 Kluitenberg, B., et al., (2012) "Comparison of vertical ground reaction forces during overground and treadmill running. A validation study." *BMC Musculoskeletal Disorders,* 1-8.

121 Schipplein, O.D, Andriacchi, T.P. (1991) "Interaction Between Active and Passive Knee Stabilizers During Level Walking." *Journal of Orthopaedic Research* 9: 113-119.

122 Nordin M. and Frankel V.H. (1989).Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

123 Taylor, W.R., Heller, M.O. et al. (2004). "Tibio-Femoral Loading During Human Gait and Stair Climbing." *Journal of Orthopaedic Research* 22: 625-632.

124 Devita, P. and Hortobagyi, T. (2003). "Obesity is Not Associated with Increased Knee Joint Torque and Power During Level Walking." *Journal of Biomechanics* 36: 1355-1362.

125 Gushue, D.L., Houck, J., Lerner, A.L. (2005). "Effects of Childhood Obesity on Three-Dimensional Knee Joint Biomechanics During Walking." *Journal of Pediatric Orthopedics* 25(6): 763-768.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the left knee. Finally, the forces created by the incident were well within the limits of human tolerance for the left knee and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Hossein, a causal link between the subject incident and claimed left knee biomechanical failures cannot be made.

Personal Tolerance Values

As noted previously, according to the available documents, Ms. Hossein. Ms. Hossein testified she worked out 5 days a week at the gym. In addition, she testified that she worked about 40 hours per week. She continued to describe that she participated in boating, jumping off the boat, and camping. The medical records confirmed these daily and recreational activities of Ms. Hossein. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Hossein and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[127]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Hossein's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Hossein using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On October 30, 2013, Ms. Elisha Hossein was the seat belted driver of a 2007 Mercedes-Benz ML350 traveling westbound on Cornell Road in Beaverton, Oregon, when the subject Mercedes-Benz was contacted in the rear at low speed by a 2002 Subaru Impreza.
2. The severity of the subject incident was significantly below 10 miles-per-hour with an average acceleration less than 3.0g
3. The acceleration experienced by Ms. Hossein was within the limits of human tolerance and comparable to that experienced during various daily activities.

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126 Kaufman, K.R., Hughes, C., et al. (2001). "Gait Characteristics of Patients with Knee Osteoarthritis." *Journal of Biomechanics* 34: 907-915.

127 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes).* (No. 960654). SAE Technical Paper Series.

4. The forces applied to the subject vehicle during the subject incident would tend to move the Ms. Hossein's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Hossein's claimed concussion. As such, a causal relationship between the subject incident and the concussion cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Hossein's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Hossein's claimed thoracic, lumbar and sacroiliac biomechanical failures. As such, a causal relationship between the subject incident and the thoracic, lumbar and sacroiliac biomechanical failures cannot be made.
8. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Hossein's claimed bilateral shoulder biomechanical failures. As such, a causal relationship between the subject incident and the bilateral shoulder biomechanical failures cannot be made.
9. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Hossein's claimed left knee biomechanical failures. As such, a causal relationship between the subject incident and the left knee biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

I hereby declare that the above statements are true to the best of my knowledge and belief, and that I understand it is made for use as evidence in court and is subject to penalty for perjury.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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May 1, 2015

Megan Schall, Claims Adjuster
Safeco Insurance Company
P.O. Box 515097
Los Angeles, CA 90051-5097

Re: *Rogers, Karen v. Charlene Fink*
ARCCA Case No.: 3271-286
Claim No.: 361902584041

Dear Ms. Schall:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces experienced by Karen Rogers. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available and the claimed injuries of the vehicle occupants, using scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the American Society of Safety Engineers, the American Society of Mechanical Engineers, and the Association for the Advancement of Automotive Medicine.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and injury potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and injury potential.

1 Nahum, A., Gomez M. (1994). Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers

2 Siegmund, G., King, D., Montgomery, D. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D. H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

Incident Description:

According to the reviewed documents, on December 20, 2011, Karen Rogers was the driver of a 1992 Ford F150 travelling eastbound on W 16th St. near the intersection of S C St. in Port Angeles, Washington. A 2003 Subaru Outback, operated by Charlene Fink, contacted the rear of the subject Ford F150. The airbags did not deploy in either vehicle and neither vehicle required towing as a result of the subject incident,

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Evergreen Collision Center-Port Angeles Estimate of Record for the incident Subaru Outback, written by Chris Ritchie, January 5, 2012
- Evergreen Collision Center-Port Angeles Estimate of Record for the subject Ford F150, written by Chris Ritchie, January 5, 2012
- Evergreen Collision Center-Port Angeles Supplement of Record, written by Chris Ritchie, January 26, 2012
- Two (2) color digital photographic reproductions of the subject Ford F150
- Two (2) color digital photographic reproductions of the incident Subaru Outback
- Transcript of Recorded Statement of Karen Rogers
- VinLink data sheet for the subject 1992 Ford F150
- Expert AutoStats data sheets for a 1992 Ford F150
- VinLink data sheets for the incident 2003 Subaru Outback
- Expert AutoStats data sheets for a 2003 Subaru Outback

Damage and Incident Severity:

The photographs of both vehicles and repair estimates for both vehicles, were utilized in analyzing the incident severity. There was only cosmetic damage to both vehicles.

Ms. Rogers stated that the impact was "loud", "sharp", and believed "the whole end of my truck came off". This is a purely qualitative description of the event. This report will provide a quantitative analysis of the subject incident.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the subject Ford F150 can be used to resolve the loads sustained by the incident Subaru Outback. That is, the loads sustained by the subject Ford are equal and opposite to those of the incident Subaru Outback.

The photographs and repair estimate of the incident Subaru indicated insignificant cosmetic damage to the front bumper cover.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Subaru Outback was used to perform a damage threshold speed change analysis.[4] The IIHS tested a 2000 Subaru Outback, essentially the same vehicle as a 2003 Subaru Outback, in a 5 mile-per-hour front impact into a rigid barrier. The test Subaru sustained damage to the front bumper reinforcement and frame sidemember reinforcements. The noted damage to the incident Subaru Outback was to the front bumper cover. Thus, because the test Subaru Outback in the IIHS front impact test sustained greater damage, the severity of the IIHS impact is greater to the severity of the subject incident and places the subject incident speed below the test speed of 5 miles-per-hour.

Furthermore, the IIHS tested multiple vehicles of the same era from the same manufacturer as the subject vehicle, as well as vehicles from other manufacturers. In a 5 mile-per-hour rear impact into a barrier, the test vehicles sustained damage comparable if not greater to the damage sustained on the subject Ford including damage to the cab of the truck due to the bed striking it. Other damage included the rear bumper mount brackets and transmission mount. In addition, testing by Nyquist et al. subjected Hybrid III test dummies to various rear truck impacts and observed the damage along with impact accelerations. The results show the rear impacts resulting in a Delta-V of 10.3 miles-per-hour or above causes the rear window to separate from the window seal and glass fracture in some cases.[5]

The above analysis is consistent with numerous low-speed impact tests indicating that the subject incident would not have the required crash pulse to produce a significant acceleration at the calculated velocity levels of the subject incident.[6] Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the maximum acceleration associated with a 5-mile-per-hour impact is 2.3g.[7] Review of the available data, engineering analyses, and my experience indicates an incident resulting in minimal accelerations to the subject Ford F150 in which Karen Rogers was seated.

Kinematic Analysis:

Using the fundamental laws of physics, as well as engineering analyses of occupant restraint systems from numerous collisions, crash tests, and sled tests, the subject Ford F150's occupant kinematic patterns and possibility of injury can be determined. The laws of physics dictate that when contact occurred between the front of the incident Subaru Outback and the rear of the subject Ford F150, had there been sufficient energy to initiate motion, the Ford would have moved forward, which would result in Karen Rogers' body moving rearward relative to the interior of the vehicle. This interaction between her and her vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Karen Rogers away from the seatback.[8] Any forward rebound would have been controlled by the available three-point

4 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

5 Nyquist, G.W., DuPont, F.T., Patrick L.M., (1984) Pick-Up Truck Rear Window Tempered Glass as a Head Restraint – Head and Neck Loads Relative to Injury Reference Criteria, (SAE 841658). Warrendale, PA, Society of Automotive Engineers.

6 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

7 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

8 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

restraint.[9] Provided the low accelerations in the subject incident, any motion of Karen Rogers would have been limited to well within the range of normal physiological limits.

Discussion:

By way of comparison, hard application of brakes results in an acceleration of approximately 0.7g, and the acceleration experienced due to gravity is 1g.[10,11] This means that Karen Rogers experiences 1g of loading while in a sedentary state. Therefore, she experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by her in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[12] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the maximum 2.3g associated with the subject incident.[13]

Previous research has shown that head and cervical spine accelerations during activities of daily living are comparable to, or greater than, the accelerations associated with the subject incident[14,15,16] For example, Vijayakumar et al. demonstrated that peak resultant linear accelerations during daily activities ranged from 2.8g to 9.9g. Therefore, as a result of the subject incident, the occupant of the subject Ford F150 would not have been exposed to any loading outside of her personal tolerance levels.[17] Rather, the accelerations experienced by Karen Rogers were comparable to, or less than, those associated with activities of daily living.

Various peer-reviewed and generally accepted investigations support these conclusions and have assessed the human response to rear-end impact accelerations. West et al.[18] subjected human volunteers to multiple rear-end collisions with barrier equivalent velocities between 2.5 and 8.5 miles

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9 Comments on Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

10 Meriam, J.L. and Kraige, L.G. (1987). Engineering Mechanics Volume 2: Dynamics (Second Edition). New York, John Wiley & Sons.

11 Baker, J. Standard and Fricke, Lynn B. (1986). The Traffic Accident Investigation Manual, At-Scene Investigation and Technical Follow-Up, Ninth Edition. Evanston, Northwestern University Traffic Institute.

12 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

13 Ng, T.P., Bussone, W.R., Duma, S.M.. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

14 Ng, T.P., Bussone, W.R., Duma, S.M. (2006) The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities Biomedical Sciences Instrumentation 42: 25-30.

15 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

16 Funk, J.R., Cormier, J.M., et al. (2007). "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

17 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

18 West, D.H., Gough, J.P., et al., (1993). "Low Speed Rear-end Collision Testing Using Human Subjects." Accident Reconstruction Journal.

per hour. Two participants reported symptoms, which were limited to minor neck pain, resolving within two days. Szabo et al.[19] subjected human volunteers with various degrees of spinal degeneration (noted via pre-test medical and radiological evaluations) to rear-end impacts with vehicle Delta-Vs comparable to that of the subject incident. Post-test medical and radiological evaluations identified no injury to any of the volunteers and no objective change in the conditions of their spines. In a study documented in the European Spine Journal, human volunteers were exposed to rear-end collisions with mean accelerations ranging from 2.1 to 3.6g.[20] Pre-test medical and radiological examinations documented that the human participants had various degrees of cervical spine degeneration. Post-test medical and radiological evaluations found no chronic cervical injuries following these collisions. Testing by Mertz and Patrick subjected a volunteer to numerous rear-end impacts, with and without a head restraint.[21] Acceleration levels of 17g were applied in the presence of a head restraint and 6g in the absence of a head restraint. Regardless, chronic cervical injuries were not reported. These data are also consistent with published guidelines for safe human exposure to rear-end impact accelerations.[22]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Karen Rogers in the subject Ford F150 was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident. As described previously, the subject incident had an average acceleration less than 2.3g. Therefore, the tests involving human volunteers and simulated crash tests that were discussed above are comparable to, or exceed, that associated with the subject incident.[23]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident and incorporated thorough analyses of the incident severity, and occupant response using peer-reviewed and generally-accepted methodologies.

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19 Szabo, T.J., Welcher, J.B., et al. (1994). Human Occupant Kinematic Response to Low-Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

20 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

21 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

22 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

23 Ito, S., Ivancic, P.C., et al. (2004). "Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" Spine 29:979-987.

ARCCA

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On December 20, 2011, Karen Rogers was the driver of the subject Ford F150 which was contacted in the rear at low speed.
2. The severity of the subject incident is consistent with a Delta-V at or below 5 miles per hour, with a maximum acceleration below 2.3g for the subject Ford F150 in which Karen Rogers was seated.
3. Had there been enough energy transferred to cause any motion, the Ford F150 would have been accelerated rearward and pushed forward, coupling Karen Rogers' motion to the vehicle, causing her body to load into seat and seat back.
4. The energy imparted to Karen Rogers in the subject Ford F150 was well within the limits of human tolerance.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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May 18, 2015

Megan Schall, Claims Adjuster
Safeco Insurance Company
P.O. Box 515097
Los Angeles, CA 90051-5097

Re: *Ake, Cari v. Joseph Myrick*
Claim No.: 446285974041
ARCCA Case No.: 3271-294

Dear Ms. Schall:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Cari Ake. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

---

1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on November 1, 2011, Ms. Cari Ake was the seat-belted driver of a 2009 Lexus IS250 traveling north on Woodland Avenue near the intersection of 80th Street East in Tulalip, Washington. Joseph Myrick was the driver of a 2002 Toyota Camry Solara traveling directly behind the subject Lexus. Mr. Myrick stated he looked down at the passenger seat and when he looked up the subject Lexus was stopping to turn. Mr. Myrick failed to stop his vehicle in time and the front of the incident Toyota contacted the rear of the subject Lexus. The airbags did not deploy in either vehicle and neither vehicle required towing as a result of the subject incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Transcript of recorded statement of Cari Ake
- Transcript of recorded statement of Joseph Myrick
- Nineteen (19) color digital reproductions of photographs of the subject Lexus IS250
- Four (4) color digital reproductions of the vehicles at the incident scene
- Safeco Insurance Company of Illinois Estimate of Record for the subject Lexus IS250, written by David Holliday, November 2, 2011
- Paramount Centre Preliminary Supplement 1 With Summary for the subject Lexus IS250 written by Russ Wyman, November 8, 2011
- Safeco Insurance Company of Illinois Supplement of Record 1 With Summary for the subject Lexus IS250, written by John Edmiston, November 11, 2011
- VinLink data sheet for the subject 2009 Lexus IS250
- Expert AutoStats data sheets for a 2009 Lexus IS250
- Expert AutoStats data sheets for the incident 2002 Toyota Camry Solara

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographs and repair estimates of the subject Lexus IS250 in association with accepted scientific methodologies. According to the available documents, the subject incident was a frontal impact between the Lexus IS250 and the Toyota Camry Solara. The primary points of impact to the incident Toyota Camry Solara and the subject Lexus IS250 were to the front and rear, respectively.

The reviewed photographs of the subject Lexus IS250 depict damage to the rear bumper cover on the left side (Figure 1).

Figure 1: Photographs of the subject 2009 Lexus IS250

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject 2009 Lexus IS250 defined by the photographic reproductions, and confirmed by the repair estimates, was used to perform a damage threshold speed change analysis.[6,7] The IIHS tested a 2007 Lexus IS250[8], essentially the same vehicle as the 2009 Lexus IS250, in a 5 kilometer-per-hour, or 3.1 mile-per-hour, rear corner impact into a simulated bumper. The test Lexus sustained damage, shown in Figure 2, to the quarter panel, rear body panel, and rear bumper cover. Thus, because the test Lexus in the IIHS rear corner impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is similar compared to the severity of the subject incident and places the subject incident at 5 kilometers -per-hour for the subject Lexus IS250. Review of the vehicle damage, incident data, published literature, scientific analyses and my experience indicates an incident resulting in a Delta-V below 5 kilometers-per-hour for the subject Lexus. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the peak acceleration associated with a 3.1 mile-per-hour impact is 1.9g.[9,10,11,12] By the laws of physics, the average acceleration experienced by the subject Lexus IS250 in which Ms. Ake was seated was less than 1.9g.

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6 Siegmund, G.P., et al., (1996). U*sing Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions.* (No. 960887). SAE Technical Paper.

7 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems.* (No. 2003-01-0492). SAE Technical Paper.

8 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2007 Lexus IS250, August 2007.

9 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration.* (No. 2000-01-0880). SAE Technical Paper.

10 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

11 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts.* (No. 970120). SAE Technical Paper.

12 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

Figure 2. Rear of IIHS test Lexus IS250

Kinematic Analysis:

Using the fundamental laws of physics, as well as engineering analyses of occupant restraint systems from numerous collisions, crash tests, and sled tests, the subject Lexus IS250's occupant kinematic patterns and possibility of injury can be determined. The laws of physics dictate that when contact occurred between the front of the incident Toyota Camry Solara and the rear of the subject Lexus IS250, had there been sufficient energy to initiate motion, the Lexus would have moved forward, which would result in Cari Ake's body moving rearward relative to the interior of the vehicle. This interaction between her and her vehicle's interior would cause her body to load into the seatback structures. Specifically, her torso and pelvis would settle back into the seatback. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Cari Ake away from the seatback.[13] Any forward rebound would have been controlled by the available three-point restraint.[14] Provided the low accelerations in the subject incident, any motion of Cari Ake would have been limited to well within the range of normal physiological limits.

13 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

14 Comments on Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

Discussion:

By way of comparison, hard application of brakes results in an acceleration of approximately 0.7g, and the acceleration experienced due to gravity is 1g.[15,16] This means that Cari Ake experiences 1g of loading while in a sedentary state. Therefore, she experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Any motion or lifting of objects by her in her daily life would have increased the loading to her body beyond the sedentary 1g. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[17] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that cervical spine accelerations during activities of daily living such as running, sitting quickly in chairs, and jumping are comparable to or greater than the maximum 1.9g associated with the subject incident.[18]

Previous research has shown that head and cervical spine accelerations during activities of daily living are comparable to, or greater than, the accelerations associated with the subject incident[19,20,21] For example, Vijayakumar et al. demonstrated that peak resultant linear accelerations during daily activities ranged from 2.8g to 9.9g. Therefore, as a result of the subject incident, the occupant of the subject Lexus IS250 would not have been exposed to any loading outside of her personal tolerance levels.[22] Rather, the accelerations experienced by Cari Ake were comparable to, or less than, those associated with activities of daily living.

Various peer-reviewed and generally accepted investigations support these conclusions and have assessed the human response to rear-end impact accelerations. West et al.[23] subjected human volunteers to multiple rear-end collisions with barrier equivalent velocities between 2.5 and 8.5 miles per hour. Two participants reported symptoms, which were limited to minor neck pain,

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15 Meriam, J.L. and Kraige, L.G. (1987). Engineering Mechanics Volume 2: Dynamics (Second Edition). New York, John Wiley & Sons.

16 Baker, J. Standard and Fricke, Lynn B. (1986). The Traffic Accident Investigation Manual, At-Scene Investigation and Technical Follow-Up, Ninth Edition. Evanston, Northwestern University Traffic Institute.

17 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

18 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." *Biomedical Sciences* Instrumentation 42: 25-30.

19 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities. Biomedical Sciences Instrumentation 42: 25-30.

20 Vijayakumar, V., Scher, I., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA: Society of Automotive Engineers.

21 Funk, J.R., Cormier, J.M., et al. (2007). "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

22 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

23 West, D.H., Gough, J.P., et al., (1993). "Low Speed Rear-end Collision Testing Using Human Subjects." Accident Reconstruction Journal.

resolving within two days. Szabo et al.[24] subjected human volunteers with various degrees of spinal degeneration (noted via pre-test medical and radiological evaluations) to rear-end impacts with vehicle Delta-Vs comparable to that of the subject incident. Post-test medical and radiological evaluations identified no injury to any of the volunteers and no objective change in the conditions of their spines. In a study documented in the European Spine Journal, human volunteers were exposed to rear-end collisions with mean accelerations ranging from 2.1 to 3.6g.[25] Pre-test medical and radiological examinations documented that the human participants had various degrees of cervical spine degeneration. Post-test medical and radiological evaluations found no chronic cervical injuries following these collisions. Testing by Mertz and Patrick subjected a volunteer to numerous rear-end impacts, with and without a head restraint.[26] Acceleration levels of 17g were applied in the presence of a head restraint and 6g in the absence of a head restraint. Regardless, chronic cervical injuries were not reported. These data are also consistent with published guidelines for safe human exposure to rear-end impact accelerations.[27]

Based upon the review of the damage to the vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Cari Ake in the subject Lexus IS250 was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect an injury mechanism in the subject incident. As described previously, the subject incident had a maximum acceleration less than 1.9g. Therefore, the tests involving human volunteers and simulated crash tests that were discussed above are comparable to, or exceed, that associated with the subject incident.[28]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident and incorporated thorough analyses of the incident severity, and occupant response using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 1, 2011, Ms. Cari Ake was the seat-belted driver of a 2009 Lexus IS250 that was contacted on the rear at low speed by a 2002 Toyota Camry Solara.

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24 Szabo, T.J., Welcher, J.B., et al. (1994). Human Occupant Kinematic Response to Low-Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

25 Castro, W.H.M., Schilgen, M., Meyer S., Weber M., Peuker, C., and Wortler, K. (1997). "Do "whiplash injuries" occur in low-speed rear impacts?" European Spine Journal 6:366-375.

26 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

27 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

28 Ito, S., Ivancic, P.C., et al. (2004). “Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation" Spine 29:979-987.

2. The severity of the subject incident was consistent with a Delta-V less than 3.1 miles-per-hour with a peak acceleration less than 1.9g for the subject 2009 Lexus IS250 in which Ms. Ake was seated.
3. Had there been enough energy transferred to cause any motion, the Lexus IS250 would have been accelerated rearward and pushed forward, coupling Cari Ake's motion to the vehicle, causing her body to load into seat and seat back.
4. The energy imparted to Cari Ake in the subject Lexus IS250 was well within the limits of human tolerance.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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July 22, 2015

Gavin Radkey, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 Second Avenue
Suite 500
Seattle, WA 98101

Re: *Swanson, Lloyd, Jr. v. James L. Geist*
Claim No.: 146307145007
ARCCA Case No.: 3271-300

Dear Mr. Radkey:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Lloyd Swanson Jr. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the testimony and other available documents, on October 6, 2013, Mr. Lloyd Swanson Jr. was the seat-belted driver of a 2011 Nissan Sentra traveling through a round-a-bout at 45th Avenue SE and College Street SE in Lacey, Washington. Mr. James Geist was the driver of a 2007 Jeep Liberty entering the round-a-bout. According to the available documents, the Jeep entered the round-a-bout, entering the Nissan's lane of travel. As a result, contact occurred between the passenger's side of the subject Nissan and the front driver's side corner of the incident Jeep. No airbags were deployed as a result of the impact.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Seven (7) color photographic reproductions of the subject 2011 Nissan Sentra
- Twelve (12) color photographic reproductions of the incident 2007 Jeep Liberty
- First National Insurance Company of America Estimate of Record for the subject 2011 Nissan Sentra [October 8, 2013]
- Extreme Auto LLC Estimate of Record for the incident 2007 Jeep Liberty [October 7, 2013]
- Recorded Statement Transcript Summary of James Geist [October 8, 2013]
- Deposition Transcript of Lloyd Swanson Jr., *Lloyd Swanson Jr. vs. James L. Geist* [February 25, 2015]
- Medical Records pertaining to Lloyd Swanson
- VinLink data sheet for the subject 2011 Nissan Sentra
- Expert AutoStats data sheets for a 2011 Nissan Sentra
- VinLink data sheet for the incident 2007 Jeep Liberty
- Expert AutoStats data sheets for a 2007 Jeep Liberty
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

1. Identify the biomechanical failures that Mr. Swanson claims were caused by the subject incident on October 6, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Swanson was occupying;
3. Determine Mr. Swanson's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident.
5. Evaluate Mr. Swanson's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Mr. Swanson attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic, Lumbar, and Lumbosacral Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the subject 2011 Nissan Sentra and incident 2007 Jeep Liberty in association with accepted scientific methodologies.[11,12]

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7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

11 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

12 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

The Estimate of Record for the subject Nissan Sentra reported damage primarily to the front bumper cover, right fender, right front wheel, right rear wheel, right rocker molding, right front door shell, right rear door shell, right quarter panel, and rear bumper cover due to the subject incident. Specifically, the rear bumper cover was repaired and not replaced. The reviewed photographs of the subject Nissan depicted a horizontal line a crush, primarily to the two passenger side doors (Figure 1). The photographs depicted scuffs/scratches to the front and rear bumper covers with some crush damage to the passenger side fender and quarter panel. Additionally, there were horizontal scratches along the entire passenger side of the subject Nissan. Mr. Swanson testified the tire indicator light came on, the passenger door was unable to open, and the Nissan started making a grinding sound from the right side.

Figure 1: Reproductions of the subject 2011 Nissan Sentra

The Estimate of Record for the incident Jeep Liberty reported damage primarily to front bumper cover, wire harness, left park and side lamp, left side marker lamp, left park lamp bulb, left fender liner, left wheel flare, and left fender liner retainer due to the subject incident. Specifically, the rear bumper cover was repaired and not replaced. The reviewed photographs of the subject Jeep depicted the driver's side front corner had minor crush to plastic components (Figure 1). No structural or significant metal components were indicated as damage in the repair records or in the reviewed photographs.

Figure 2: Reproductions of the incident 2007 Jeep Liberty

Scientific analyses of the photographs and geometric measurements of the vehicles along with the available testimony, identified that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces. As such, the subject incident was consistent with a sideswipe event.[13] The laws of physics dictate that the lateral force exerted to the front bumper of the subject Nissan Sentra was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the incident as a result of the sideswipe event was less than 2.0g.[14] Using an acceleration pulse with the shape of a haversine and duration of 200 milliseconds,[15] the Delta-V associated with the subject incident is 4.3 mph. The lateral forces to the Nissan Sentra associated with the subject incident were calculated to be insignificant. Additionally, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the angled front impact test of a 2002 Jeep Liberty at 5 mph was consistent with the above analysis.

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13 Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

14 Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions, (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

15 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that Mr. Swanson experiences 1g of loading while in a sedentary state. Therefore, Mr. Swanson experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[16] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Mr. Swanson testified he had both hands on the steering wheel with one foot on the brake and one foot on the floor. He testified that he was not braced for the impact and he struck the driver's side door due to the impact. Due to the impact, Mr. Swanson testified the Nissan was pushed partially into the next lane. Further, Mr. Swanson testified he was wearing the available three point restraint.

The laws of physics dictate that had there been enough energy transferred to initiate motion, the sideswipe event would have caused the subject Nissan to decelerate longitudinally and accelerate slightly leftward. Scientific literature indicates that provided the low accelerations of the event, little occupant motion would have occurred.[17,18] ARCCA, Incorporated has conducted experiments that exposed motor vehicles to low severity contact events similar to the subject incident. These experiments included tracking the movement of human volunteers and anthropomorphic test devices (ATDs) during the testing. Results demonstrated that neither the human volunteers nor the ATDs experienced any significant motion relative to the vehicle's interior. If occupant motion were assumed to have occurred during the subject incident, the laws of physics and results from previous studies[19,20] dictate that Mr. Swanson would have tended to move forward and rightward relative to the vehicle's interior. This motion would have been controlled and supported by the friction generated at his seat bottom, the center console and the three point restraint. Specifically, the three-point restraint would have locked during the subject incident had the acceleration exceeded 0.7g and limited his forward body excursion.[21] Provided the low accelerations of the subject incident, and the supports described, the bodily response of Mr. Swanson would have been limited to well within normal physiological limits

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16 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

17 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

18 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

19 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

20 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

21 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Swanson was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

Mr. Swanson was diagnosed with a cervical, thoracic, lumbar, and lumbosacral sprain/strain. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

As described previously, the sideswipe event would have caused the subject Nissan Sentra to decelerate longitudinally and accelerate leftward. Scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, little occupant motion would have occurred.[24,25] If occupant motion were assumed, Mr. Swanson would have moved forward and rightward relative to the vehicle's interior.[26,27] This

[22] Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

[23] Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

[24] Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

[25] Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

[26] Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

[27] Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Nissan. Mr. Swanson's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[28] As a result, Mr. Swanson's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[29]

Many research studies support these above conclusions. Human volunteers have been exposed to frontal and lateral impact accelerations at levels comparable to, and greater than that of the subject incident.[30,31,32,33,34,35,36,37,38,39,40] Participants moved toward the point of impact while their response was controlled by the three-point restraint, seat structures, and vehicle interior components. None of the volunteers reported cervical trauma in response to this testing. Further research has exposed cadavers to impact accelerations within the biomechanical failure range.[41,42] These results demonstrated that the accelerations during the subject incident were maintained well within human tolerance as none of the cadaveric testing resulted in cervical trauma at acceleration levels consistent with the subject incident. The accelerations during the subject incident were maintained within published guidelines for safe human exposure to frontal and lateral impact accelerations.[43] In addition, these studies demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

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28 Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

29 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

30 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

31 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

32 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

33 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

34 Matsushita, T., Sato, T.B., Hirabayashi, K., et al. (1994). X-ray Study of the Human Neck Motion Due to Head Inertia Loading (SAE 942208). Warrendale, PA. Society of Automotive Engineers.

35 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

36 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

37 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

38 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

39 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

40 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

41 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

42 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

43 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[44,45] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Research by Funk et al.[46] demonstrated that a simple head shake or a self-inflicted hand strike to the head induces accelerations comparable to or greater than the subject incident. Mr. Swanson performed daily activities without biomechanical failure prior to the subject incident. Mr. Swanson testified he worked in construction and performed several exercises regularly. These activities would have generated cervical forces that were comparable to and greater than those of the subject incident.[47,48,49,50] These data demonstrate that the cervical forces of the subject incident did not exceed Mr. Swanson's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Swanson cannot be made.

Thoracic, Lumbar, and Lumbosacral Spine

In this type of collision, the motion of Mr. Swanson's thoracic, lumbar, and lumbosacral regions would have been well supported and constrained. Again, scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, little occupant motion would have occurred.[51,52] Provided sufficient energy to overcome Mr. Swanson's muscle reaction forces, his body would have moved forward and rightward relative to the Nissan's interior. As described previously, Mr. Swanson testified he was wearing the available three-point restraint. The three-point restraint would have locked during the subject

44 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

45 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

46 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

47 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." Biomedical Sciences Instrumentation 42: 25-30.

48 Vijayakumar, V., Scher, I., Gloeckner, D.C., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA. Society of Automotive Engineers.

49 Choi, H., and Vanderby, R. (2000). "Muscle Forces and Spinal Loads at C4/5 Level During Isometric Voluntary Efforts." Medicine & Science in Sports & Exercise 830-838.

50 Moroney, S.P., Schultz, A.B., and Miller, J.A.A. (1988). "Analysis and Measurement of Neck Loads." Journal of Orthopaedic Research 6: 713-720.

51 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

52 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

incident and limited his forward body excursion.[53] The seat belt would have primarily engaged Mr. Swanson's bony left clavicle and pelvis distributing the load over his entire torso and limiting his motion. Therefore, Mr. Swanson's thoracic, lumbar, and lumbosacral spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Mr. Swanson's thoracic, lumbar, and lumbosacral spine during the subject incident would have been limited to within normal physiologic limits.

Researchers have frequently exposed human volunteers to both frontal and lateral impact accelerations at levels comparable to and greater than that of the subject incident.[54,55,56,57,58,59,60,61] No thoracic or lumbar biomechanical failures were reported and kinematics documented. Additionally, occupant kinematics were inconsistent with the biomechanical failure mechanism responsible for the thoracic and lumbar failures. Published guidelines for safe human exposure to frontal and lateral impacts are consistent with the results from these studies.[62] These data provide support for the conclusions described previously regarding Mr. Swanson's response to the subject incident. In addition, these data demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

The subject incident had a peak acceleration below 2.0g. Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[63] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[64] Mr. Swanson testified he worked in construction and performed exercises such as squats, pushups, and football with his brothers. Studies by Rohlmann et al.[65,66,67] have shown that seemingly benign tasks such as flexion of the upper body while

53 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

54 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

55 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

56 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

57 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

58 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

59 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

60 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

61 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

62 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

63 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

64 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

65 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable or greater than those resulting from subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic, lumbar, and lumbosacral spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic, lumbar, and lumbosacral spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Swanson, a causal link between the subject incident and claimed thoracic, lumbar and lumbosacral biomechanical failures cannot be made.

Personal Tolerance Values

As noted previously, according to the testimony and other available documents, Mr. Swanson worked in construction. Further, he testified that he was capable of scrubbing the floor, cleaning dishes, and general work in the house. Mr. Swanson testified he exercised including running and working out. Daily activities can produce greater movement, or stretch, to the soft tissues of Mr. Swanson and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[68]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Swanson's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Swanson using peer-reviewed and generally-accepted methodologies.

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66 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

67 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

68 Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

ARCCA

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On October 6, 2013, Mr. Lloyd Swanson Jr. was the seat-belted driver of a 2011 Nissan Sentra that was contacted in the passenger's side by a 2007 Jeep Liberty resulting in a sideswipe collision.
2. The severity of the subject incident was consistent with a Delta-V less than 4.3 miles-per-hour with peak acceleration less than 2.0g for the subject 2011 Nissan Sentra in which Mr. Swanson was seated.
3. The acceleration experienced by Mr. Swanson was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. Had the forces of the subject incident been sufficient to overcome the muscle reaction forces, Mr. Swanson's body would have moved forward and rightward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Swanson's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Swanson's claimed thoracic, lumbar, and lumbosacral biomechanical failures. As such, a causal relationship between the subject incident and the thoracic, lumbar, and lumbosacral biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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August 13, 2015

Earle Bravo, Esquire
Reed McClure
1215 Fourth Avenue
Suite 1700
Seattle, WA 98161

Re: *Pristupa, Irina v. Tower Group Insurance Companies*
ARCCA File Number: 4376-007

Dear Mr. Bravo:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces experienced by Ms. Irina Pristupa. This analysis is based on information currently available to ARCCA and is to only be issued in its entirety. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My scientific evaluations and test programs have focused on exploration of human biomechanical failure causation in a variety of loading environments and have included test subjects such as human volunteers, live-surrogates, cadavers, and anthropomorphic test devices. I have conducted full-scale automotive crash tests and sled tests that implemented various reconstruction techniques to assess incident severity, occupant response, injury causation, and injury prevention strategies. Further research has included development and testing of restraint systems. Therefore, I am very familiar with the theory and application of restraint systems, and

1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance. Throughout this research and analysis, I have evaluated the various aspects of the human body and assessed the effects of age, degeneration, and surgical interventions on the kinematic and kinetic response of the human body when exposed to potentially injurious environments. This training and experience has provided a unique understanding of physics and engineering in the context of human anatomy and physiology, enabling me to perform a thorough scientific evaluation.

Incident Description:

According to the State of Washington Police Traffic Collision Report and reviewed documents, on March 7, 2013, Ms. Irina Pristupa was the belted driver of a 2002 Honda Odyssey traveling eastbound on State Route 500 just east of 152nd Avenue in Vancouver, Washington. Nicola Mease was the driver of a 2001 Nissan Altima traveling behind the subject Honda. The incident Nissan failed to stop in time and the front of the incident Nissan contacted the rear of the subject Honda. The subject Honda was subsequently pushed forward and contacted the rear of a 2007 Ford E-150 cargo van. The incident van subsequently contacted a 2007 Dodge Ram 1500.

Materials Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report
- Ten (10) color digital photographic reproductions of the vehicles at the incident scene
- Deposition transcript of Irina Pristupa, April 24, 2015
- Report of Advanced Medical Group, Inc., June 12, 2015
- Vinlink data sheet for the subject 2002 Honda Odyssey
- Expert AutoStats data sheets for a 2002 Honda Odyssey
- Vinlink data sheet for the incident 2001 Nissan Altima
- Expert AutoStats data sheets for a 2001 Nissan Altima
- Vinlink data sheet for the incident 2007 Ford E-150
- Expert AutoStats data sheets for a 2007 Ford E-150
- Vinlink data sheet for the incident 2007 Dodge Ram 1500
- Expert AutoStats data sheets for a 2007 Dodge Ram 1500
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards

Vehicle Damage and Incident Severity:

The severity of the subject incident was evaluated using the photographs, testimony, and damage reported within available documents in accordance with accepted engineering practices. The available documents indicated that the subject incident involved rear and frontal contact to the subject Honda Odyssey.

The damage pattern to the front of the incident Nissan indicated that there was rearward deformation to the hood and grill area. These data indicate that the subject incident involved some degree of underride/override wherein the front bumper assembly of the incident Nissan rode under the rear bumper assembly of the subject Honda.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Nissan can be used to resolve the loads sustained by the subject Honda. That is, the loads sustained by the incident Ford are equal and opposite to those of the subject Honda.

An energy based crush analysis of a 2001 Nissan Altima was performed to evaluate the severity of the subject incident. This methodology has demonstrated validity and accuracy for determining the severity of automobile collisions.[6,7,8,9,10] This analysis demonstrated that a single 10 mph Delta-V (difference in pre- and post-impact vehicle velocity) impact to the front of a 2001 Nissan Altima would result in significant residual crush damage, causing a maximum crush depth of 3.75 inches across the full width and height of the front of the vehicle. A peer-reviewed and generally-accepted methodology for conducting residual crush measures calls for averaging the resulting deformation to determine the critical residual crush when an underride/override condition is present.[11] Analysis of the Nissan photographs as well as geometric measurements of a 2001 Nissan Altima identified that the residual crush damage imparted as a result of the subject incident was less than the pre-averaged value of 7.5 inches. Based on these results, the presence of the underride/override condition, and the damage reported within the available documents, significantly greater deformation would occur in a 10 mph rear end Delta-V impact than was reported as a result of the subject incident. The lack of significant residual crush indicates that the incident Nissan sustained a Delta-V impact that was less than 10 mph.

Utilizing the analyses described above, the principles of engineering, and the conservation of momentum,[12] the subject incident would have caused a rear-end Delta-V impact to the subject Honda that was on the order of 8.0 mph.[13,14] Using an acceleration pulse in the shape of a haversine and duration of 200 milliseconds, the average acceleration associated with an 8.0 mph Delta-V impact is 1.8g.[15] As a result, the subject Honda in which Ms. Pristupa was driving

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6 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

7 Day, T.D. and Siddall, D.E. (1996). Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment. (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

8 Day, T.D. and Hargens, R.L. (1985). Differences Between EDCRASH and CRASH3 (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

9 Day, T.D. and Hargens, R.L. (1989). Further Validation of EDCRASH Using the RICSAC Staged Collisions (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

10 Day, T.D. and Hargens, R.L. (1987). An Overview of the Way EDCRASH Computes Delta-V (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

11 Tumbas, N.S., and Smith, R.A., (1988). Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

13 Tanner, C.B., Wiechel, J.F., Bixel, R.A., et al., (2001). Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations (SAE 2001-01-0891). Warrendale, PA, Society of Automotive Engineers.

14 Howard, R.P., Bomar, J., et al. (1993). Vehicle Restitution Response in Low Velocity Collisions (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

15 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

during the described incident was exposed to a Delta-V impact that was less than 8.0 mph with an effective acceleration level less than 1.8g for the rear impact phase of the subject incident.

Utilizing the conservation of momentum,[16] the subject incident would have caused a front-end Delta-V impact to the subject Honda that was on the order of 5.0 mph.[17,18] Using an acceleration pulse in the shape of a haversine and duration of 200 milliseconds, the average acceleration associated with a 5.0 mph Delta-V impact is 1.1g.[19] As a result, the subject Honda in which Ms. Pristupa was driving during the described incident was exposed to a Delta-V impact that was less than 5.0 mph with an effective acceleration level less than 1.1g for the frontal impact phase of the subject incident.

Kinematic Analysis:

The motions (kinematics) of Ms. Pristupa within the subject Honda during the described incident were evaluated using the laws of physics and engineering analyses of occupant restraint systems based on various collision scenarios, crash tests, and sled tests. The laws of physics dictate that provided sufficient energy to initiate motion, rear contact to the subject Honda would have caused forward acceleration/motion of the vehicle. Had the subject incident generated sufficient force to overcome Ms. Pristupa's muscle reaction forces, her body would have moved rearward relative to the Honda's interior.[20,21,22] This rearward motion would have been supported and constrained by the available seatback and head restraint.

Purpose of Seat Belt Restraints

The necessity to restrain occupants within vehicles to provide protection during crashes has been well known for many years in the occupant crash protection area in general, and in the automobile industry in particular. It has also been the subject of numerous public safety campaigns and advertisements. Occupant crash protection has traditionally been provided through the use of seat belts. The purpose of a seat belt is threefold:[23]

1. To prevent occupant ejection from the vehicle;
2. To couple the occupant to the vehicle and thus take advantage of the energy management properties provided by the crush of the vehicle's structure, thereby allowing the occupant to "ride down" the forces produced during the crash; and

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16 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

17 Tanner, C.B., Wiechel, J.F., Bixel, R.A., et al., (2001). Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations (SAE 2001-01-0891). Warrendale, PA, Society of Automotive Engineers.

18 Howard, R.P., Bomar, J., et al. (1993). Vehicle Restitution Response in Low Velocity Collisions (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

19 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

20 Anderson, R.A., W.J.B., et al. (1998). Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions (SAE 980298). Warrendale, PA, Society of Automotive Engineers.

21 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

22 Matsushita, T., Sato, T.B., Hirabayashi, K., et al., (1994). X-ray Study of the Human Neck Motion Due to Head Inertia Loading (SAE 942208). Warrendale, PA, Society of Automotive Engineers.

23 NHTSA Standardized Child Passenger Safety Training Program: Participant Manual. Spring 2001.

3. To minimize the “second collision” of the occupant against the interior surfaces of the vehicle.

Seat belts are designed to distribute loads to the strong bony portions of the occupant. By applying restraining forces to the strong areas of the occupant’s body, such as the pelvis, chest, and shoulders, properly designed and worn seat belts are able to prevent the “second collision” for most crashes. By preventing or minimizing the impact of the “second collision,” the forces applied to the occupants are controlled or reduced. By reducing or applying loads only to the strong bony portions of the body, the potential and severity of any injuries to the occupant are minimized or eliminated.

Expected Kinematics of a Properly Restrained Occupant

The National Highway Traffic Safety Administration has a legislative mandate to issue Federal Motor Vehicle Safety Standards (FMVSS) and regulations to which manufacturers of motor vehicles and associated equipment must conform and certify compliance. FMVSS 209, which specifies requirements for seat belt assemblies, dictates that seat belt retractors lock when accelerations exceed 0.7g.[24]

The fundamental laws of physics, as well as the scientific analysis of occupant restraint systems from numerous collisions and crash tests indicate Ms. Pristupa’s kinematics. As previously described, during the frontal impact phase of the subject incident, the Honda Odyssey would have been decelerated longitudinally upon contact with the Ford van. Ms. Pristupa would have continued to move at her pre-impact speed and direction. This process would have resulted in forward rightward motion of Ms. Pristupa’s body relative to the interior of the Honda. As the Honda decelerated, the seat belt retractors would have locked at or before the accelerations exceeded 0.7g, and the three point restraint would have distributed the loads between the pelvis and torso of Ms. Pristupa’s body, thereby reducing the forward motion of her body and coupling her to the vehicle.

Discussion:

Several peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to rear-end impact accelerations. Szabo et al.[25] conducted vehicle rear-end impacts with human volunteers. The struck vehicle Delta-V approached or exceeded 5 mph. Pre-test medical and radiological evaluations noted some participants had various degrees of spinal degeneration (including intervertebral disc bulges and protrusions). Post-test medical and radiological evaluations found no injury to any of the volunteers, and no objective change to the pre-test conditions of their spines. Nielsen et al.[26] conducted a series of aligned collisions involving human participants. No chronic injuries were reported following repeated tests involving Delta-V impacts exceeding 5 mph. West et al.[27] subjected human volunteers to multiple rear-end impacts with barrier equivalent velocities from 2.5 to 8.5 mph. Reported

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24 Federal Motor Vehicle Safety Standard 209: Seat Belt Assemblies, 49 CFR 571.209.

25 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

26 Nielsen, G.P., Gough, J.P., Little, D.M., et al., (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

27 West, D. H., J. P. Gough, et al. (1993). "Low Speed Rear-End Collision Testing Using Human Subjects." Accident Reconstruction Journal.

symptoms were limited to minor neck pains by two volunteers that resolved within two days. The authors indicated these symptoms were likely the result of multiple tests. Braun et al.[28] conducted vehicle-to-vehicle rear end impacts with human volunteers and a target vehicle Delta-V ranging from 1.5 to 4.5 mph. Minor neck soreness was reported by three volunteers which resolved within two days. Live human subjects have also been exposed to rear-end impact accelerations exceeding 40g without acute onset of trauma to the thoracic spines.[29,30]

Review of the available materials indicated that Ms. Pristupa was capable of performing normal daily activities. Ms. Pristupa was employed as a cab driver at the time of the subject incident. She described working up to 70 to 75 hours per week. The joints of the human body are regularly and repeatedly subjected to a wide range of loads during daily activities. Almost any movements beyond a sedentary state can result in short duration joint loads of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of producing such loads.[31] More dynamic events, such as running, jumping, or jogging can increase short duration joint load to as much as ten times body weight.[32] Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration. Previous research has shown that lumbar loads generated during activities of daily living such as running, sitting quickly in a chair, and jumping were comparable to or greater than the loads associated with the subject incident.[33] Research by Rohlmann et al.[34] has shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, can generate loads that were comparable to or greater than those resulting from the subject incident.

The available three-point restraint that Ms. Pristupa was wearing at the time of the subject incident would have distributed the loads across her pelvis, left clavicle, and torso, allowing for ride down during the subject incident. This interaction would reduce the motion of her body and prevent her chest from contacting the front passenger seat during the impact phase of the subject incident. Additionally, friction between her body and the seat bottom would have aided in limiting her motion. Due to the nature of the subject incident, any forces applied to Ms. Pristupa's cervical spine would have been directed primarily along a horizontal plane, thereby minimizing vertical compressive forces.[35] As a result, Ms. Pristupa's cervical spine motion would have been well controlled and any loading forces applied would have been maintained within physiologic limits.[36,37]

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28 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). Rear-end Impact Testing with Human Test Subjects (SAE 2001-01-0168). Warrendale, PA, Society of Automotive Engineers.

29 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006

30 Eiband, A.M. (1959) "Human Tolerance to Rapidly Applied Accelerations: A Summary of Literature." National Aeronautics and Space Administrations Memorandum 5-19-59E.

31 Mow, V. C. and W. C. Hayes (1991). Basic Orthopaedic Biomechanics. New York, Raven Press.

32 Nahum, A.M. and J. Melvin (1985). The Biomechanics of Trauma. Connecticut, Appleton-Century-Crofts

33 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "Thoracic and Lumbar Spine Accelerations in Everyday Activities." Biomedical Sciences Instrumentation 42: 410-415.

34 Rohlmann, A., Claes, L.E., et al. (2001). "Comparison of Intradiscal Pressures and Spinal Fixator Loads for Different Body Positions and Exercises." Ergonomics 44 (8): 781-794.

35 Millington, S.A., Tomasch, E., Mayrhofer, E. et al. (2005). High-Speed X-ray Assessment of the Bony Kinematics of the Cervical Spine during Frontal Impacts (SAE 2005-01-0309). Warrendale, PA. Society of Automotive Engineers.

36 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

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Data collected from various research endeavors support these conclusions.[38] Researchers have frequently used cadavers to assess cervical spine failure potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause cervical biomechanical failure are greater than those associated with the subject incident.[39,40] Arbogast et al.[41] subjected human volunteers to 3g frontal impacts without any reported pain, stiffness, or biomechanical failure to any participants. Matsushita et al.[42] subjected human volunteers to frontal impacts at severity levels comparable to that of the subject incident. None of the participants reported any cervical biomechanical failures following these tests. These data are consistent with guidelines for safe human exposure to frontal impacts.[43]

Conclusions:

Based upon a reasonable degree of biomedical engineering certainty, I conclude the following:

1. On March 7, 2013, Ms. Irina Pristupa was the belted driver of a 2002 Honda Odyssey that was contacted at the rear by a 2001 Nissan Altima. The front of the subject Honda Odyssey subsequently contacted the rear of a 2007 Ford E-150 van.

2. The severity of the subject incident was consistent with a change in velocity (Delta-V) for the subject Honda in which Ms. Pristupa was driving that was less than 8.0 mph with an effective acceleration level less than 1.8g for the rear impact phase.

3. The severity of the subject incident was consistent with a change in velocity (Delta-V) for the subject Honda in which Ms. Pristupa was driving that was less than 5.0 mph with an effective acceleration level less than 1.1g for the frontal impact phase.

4. Had the loads associated with the rear-end phase been sufficient to overcome Ms. Pristupa's muscle reaction forces, her body would have moved rearward relative to the Honda's interior. This motion would have been limited and well controlled by the seatback and head restraint.

5. Had the loads associated with the front-end phase been sufficient to overcome Ms. Pristupa's muscle reaction forces, her body would have moved forward relative to the Honda's interior. This motion would have been limited and well controlled by the three-point restraint system.

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37 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

38 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

39 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

40 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

41 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

42 Matsushita, T., Sato, T.B., Hirabayashi, K., et al. (1994). X-ray Study of the Human Neck Motion Due to Head Inertia Loading (SAE 942208). Warrendale, PA. Society of Automotive Engineers.

43 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

6. The loads that Ms. Pristupa was exposed to during the subject incident were well within the limits of human tolerance.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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August 28, 2015

[redacted]

[redacted]

Dear [redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the event sequences. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomedical engineering, utilizing scientific and engineering methodologies generally accepted in the automotive industry.[1,2,3]. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the American Society of Safety Engineers, the American Society of Mechanical Engineers, and the Association for the Advancement of Automotive Medicine.

<u>Incident Description</u>:

According to the State of Washington Police Traffic Collision Report, on December 23, 2013, [redacted] was the driver of a 1996 Chevrolet Blazer travelling eastbound on NE 12th Street at the intersection of Kirkland Avenue NE in Renton, Washington. [redacted] was the driver of a 2011 Toyota Camry travelling westbound on NE 12th Street at the intersection of Kirkland Avenue NE. [redacted] stated that after stopping for the stop sign he turned left and his vehicle was struck by the Toyota Camry, which he claims did not stop for the stop sign. [redacted] stated that he stopped for the stop sign, proceeded forward, and the Chevrolet Blazer turned in front of his vehicle.

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1 Fricke, Lynn B. (1990). Traffic Accident Reconstruction. Volume 2 of the Traffic Accident Investigation Manual. Evanston, Northwestern University Traffic Institute.
2 Sears, Zemansky and Young, University Physics, March 1977
3 Baumeister, T., Avallone, E.A. and Baumeister, T. (1978). <u>Mark's Standard Handbook for Mechanical Engineers</u>. Eighth Edition. New York, McGraw-Hill.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report
- Deposition transcript of [redacted], July 20, 2015
- Plaintiff's Amended Response To Defendants' Request For Statement Of Damages Pursuant To RCW 4.28.360
- Deposition transcript of [redacted], with exhibits, July 21, 2015
- Plaintiff Cruz' Responses To Defendant [redacted] First Set Of Interrogatories And Requests For Production Of Documents
- Complaint For Damages Auto Tort
- Defendant [redacted] Answer To Plaintiff's Complaint For Damages Auto Tort
- VinLink data sheet for the 1996 Chevrolet Blazer
- Expert AutoStats data sheets for a 1996 Chevrolet Blazer
- VinLink data sheet for the 2011 Toyota Camry
- Expert AutoStats data sheets for a 2011 Toyota Camry

Discussion:

[redacted] testified that he brought his vehicle to a stop at the stop sign. He further testified that he then moved his vehicle forward. He also testified that the [redacted] vehicle did not stop, turned left in front of his vehicle, and contacted his vehicle on the left side.

[redacted] testified that he brought his vehicle to a stop at the stop sign. He testified that he was stopped for ten seconds. He testified that the [redacted] vehicle was "speeding" and "did not respect" the stop sign. He testified that he observed the [redacted] vehicle for the full ten seconds. He further testified that he first observed the [redacted] vehicle when it was ten meters from the intersection. He testified that he started to turn left when the [redacted] vehicle was ten meters from the intersection. Finally, he testified that he started to turn, observed the [redacted] vehicle, and then tried to move ahead.

The testimony of [redacted] is consistent with the available data. There is no objective data to prove within a reasonable degree of scientific certainty that the testimony of [redacted] is inaccurate.

The testimony of [redacted] is not consistent with the available data. [redacted] initially testified that the [redacted] vehicle was speeding and he observed the vehicle for 10 seconds. The posted speed limit is 35 miles-per-hour. This is equivalent to 51 feet per second. Therefore, this indicates that the [redacted] vehicle was 510 feet from the intersection when first observed. There would be adequate time to complete the turn with this distance. This is also inconsistent with [redacted] testimony that he had turned right onto NE 12th Street a block before the intersection. The first intersection east of the subject intersection is approximately 280 feet away. It would not be possible to observe the [redacted] vehicle for 500 feet. [redacted] subsequently testified that he first observed the [redacted] vehicle 10 meters away from the intersection. If he observed the [redacted] vehicle for 10 seconds and it travelled 10 meters it would be travelling at 1 meter per second or 2.2 miles-per-hour. If the [redacted] vehicle was observed from 10 meters

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prior to the intersection to the point of contact it is approximately 20 meters. This changes the rate of travel to 4.47 miles-per-hour. Both of these speeds are not consistent with speeding. It would be easy to take evasive actions to avoid the collision at these speeds. Finally, [redacted] testified that he tried to move ahead, after initiating his turn and observing the [redacted] vehicle. This indicates that [redacted] did not attempt to slow his vehicle or turn his vehicle to avoid contact between the two vehicles, but chose to continue forward or accelerate.

Conclusions:

Based upon a reasonable degree of engineering and biomedical engineering certainty, I conclude the following:

1. On December 23, 2013, [redacted] was the driver of a Chevrolet Blazer, which was involved in a motor vehicle incident with a 2011 Toyota Camry, driven by [redacted]
2. The testimony of [redacted] is consistent with the available data.
3. The testimony of [redacted] is not consistent with the available data.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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September 21, 2015

Kelsey Farnam, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Scott, Walter v. Tracey & Jennifer Rex*
Claim No.: 8724 4321 5041
ARCCA Case No.: 3271-325

Dear Ms. Farnam:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Walter Scott. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.
2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.
3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.
4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.
5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on November 8, 2012, Mr. Walter Scott was the seat-belted driver of a 2012 Chevrolet Cruze traveling on Central Way near 3rd Street in Kirkland, Washington. Ms. Tracy Rex was the driver of a 2008 Mercedes-Benz GL320 traveling directly in front of the Chevrolet Cruze. The Mercedes-Benz turned into a parking area followed by the Chevrolet Cruze, and proceeded partway before both vehicles stopped. Contact was then made between the rear of the Mercedes-Benz and the front of the Chevrolet. No airbags were deployed in either vehicle and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) color photographic reproductions of the subject 2012 Chevrolet Cruze
- Seven (7) color photographic reproductions of the incident 2008 Mercedes-Benz GL320
- Juanita Collision Center, LLC. Estimate of Record for the subject 2012 Chevrolet Cruze [November 29, 2012]
- Bodyworks Auto Rebuild repair estimate for the incident 2008 Mercedes-Benz GL320 [November 18, 2012]
- Deposition Transcript of Walter Scott, *Walter Scott vs. Tracy Rex and Jennifer Rex* [July 23, 2015]
- Recorded Statement Transcript of Walter Scott
- Recorded Statement Transcript of Tracy Rex [November 9, 2012]
- Medical Records pertaining to Walter Scott
- VinLink data sheet for the subject 2012 Chevrolet Cruze
- Expert AutoStats data sheets for a 2012 Chevrolet Cruze
- VinLink data sheet for the incident 2008 Mercedes-Benz GL320
- Expert AutoStats data sheets for a 2008 Mercedes-Benz GL320
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Mr. Scott claims were caused by the subject incident on November 8, 2012;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2012 Chevrolet Cruze;
3. Determine Mr. Scott's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. Scott's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Mr. Scott attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair estimates of the subject 2012 Chevrolet Cruze and the incident 2008 Mercedes-Benz GL320 in association with accepted scientific methodologies. [11,12]

The repair estimate for the subject Chevrolet Cruze reported damage to the front bumper cover, front emblem, upper/center grille, left headlamp assembly, fog lamps, and inner edge of the hood, which is consistent with the reviewed photographs (Figure 1). The photographs depicted minor residual crush to the left front of the hood, as well as the lower left of the bumper near the fog lamp. Both Mr. Scott and Ms. Rex noted damage to the front driver's side of the Chevrolet Cruze.

Figure 1: Reproductions of photographs of the subject 2012 Chevrolet Cruze

The repair documents for the incident 2008 Mercedes-Benz GL320 indicated there was damage to the left wheelhouse liner, energy absorber, lower cover and shield, left reflector, left muffler and tailpipe, and rear bumper cover. The photographs depicted damage to the left rear bumper, and displacement of the left tailpipe and muffler (Figure 2). Both Mr. Scott and Ms. Rex noted damage to the rear driver's side of the Mercedes-Benz GL320.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 2: Reproductions of photographs of the incident 2008 Mercedes-Benz GL320

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 2012 Chevrolet Cruze revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the front of a Chevrolet Cruze of the same production year would result in significant and visibly noticeable crush across the entirety of the subject Cruze's front structure, with a residual crush of 2.25 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject

[13] Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

[14] Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

[15] Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

[16] Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

[17] Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

[18] EDCRASH, Engineering Dynamics Corp.

[19] PC-Crash Collision Software.

incident.[20] The lack of significant structural crush to the entire front of the subject Chevrolet Cruze indicates a collision resulting in a Delta-V significantly below 10 miles per hour. [21,22,23,24,25,26]

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[27,28,29,30] By the laws of physics, the average acceleration experienced by the subject Chevrolet Cruze in which Mr. Scott was seated was significantly less than 3.0g. This analysis is consistent with the IIHS low-speed crash test for a comparable vehicle by the same manufacturer and other vehicles from the same era. [31]

The acceleration experienced due to gravity is 1g. This means that Mr. Scott experiences 1g of loading while in a sedentary state. Therefore, Mr. Scott experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[32] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Mr. Scott's medical records indicated he was 71 inches in height, weighed approximately 196 lbs., and was 40 years old at the time of the subject incident. Mr. Scott testified that his body did not make any contact with the interior of the vehicle, and his vehicle did not move after contact. In a recorded statement, Mr. Scott stated his head may have contacted the headrest. According to the available medical records, Mr. Scott also stated that his head and back thrust back and forth in his seatbelt, and that the Mercedes-Benz was traveling 5 miles per hour.

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20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

21 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2010 Honda CR-V into 2010 Honda Civic, December 2010.

22 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

23 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

24 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

25 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

26 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

27 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

28 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

29 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

30 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

31 Insurance Institute for Highway Safety Bumper Evaluation Crash Test Report. 2008 Chevrolet HHR, September 2008.

32 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

The laws of physics dictate that when the subject Chevrolet Cruze was contacted in the front, it would have been pushed rearward causing Mr. Scott's seat to move backward relative to his body. This motion would result in Mr. Scott moving forward relative to the interior of the subject vehicle and loading into the lap and shoulder restraints, before his torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Mr. Scott was wearing the available three point restraint. As Mr. Scott's body moved forward the seat belt locking mechanism would engage and restrict additional forward motion of his torso and pelvis. Any rebound would have been within the range of protection afforded by the seatback and head restraint structures. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Scott would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Scott was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[33,34]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a frontal impact that produces motion of the subject vehicle, the Chevrolet Cruze would be pushed backward and Mr. Scott would have moved forward relative to the vehicle, until his motion was stopped by the lap and shoulder restraints. The seat belt would have locked and the lap and shoulder belts would have distributed the loads amongst his pelvis and torso, thereby reducing the motion of his body and preventing his head from contacting frontal interior vehicle structures during the subject incident. Mr. Scott's cervical spine would have been subjected to a

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33 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

34 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

controlled degree of flexion during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact.[35] A kinematic analysis of Mr. Scott's response to the subject incident demonstrated that his overall head motion would have been minimal.[36,37] Frontal impact research involving human volunteers demonstrated that at severity levels comparable to the subject incident, head motion was predominately self-limiting.[38] As a result, Mr. Scott's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[39]

Numerous peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to frontal impact accelerations utilizing human volunteers.[40,41] The Delta-V of the striking vehicle was comparable to or greater than that associated with the subject incident, and no chronic cervical biomechanical failures were reported. Several researchers have used cadavers to assess cervical spine biomechanical failure potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause chronic cervical biomechanical failure are greater than that associated with the subject incident.[42,43] Specifically, studies performed by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[44] None of the participants reported any chronic cervical biomechanical failures. Additional human volunteer testing subjected participants to frontal impacts between 3g and 15g without any permanent physiological changes to their cervical spine and only minor neck stiffness to any participants.[45,46]

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Ng et al.,[47,48] measured accelerations of the head and spinal structures during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap

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35 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

36 Araszewski, M., Roenitz, E., and Toor, A., (1999). Maximum Head Displacement of Vehicle Occupants Restrained by Lap and Torso Belts in Frontal Impacts (SAE 1999-01-0443). Warrendale, PA, Society of Automotive Engineers.

37 Happer, A.J., Hughes, M.C., Simeonovic, G.P., (2004). Occupant Displacement Model for Restrained Adults in Vehicle Frontal Impacts (SAE 2004-01-1198). Warrendale, PA, Society of Automotive Engineers.

38 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

39 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

40 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

41 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

42 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

43 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

44 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

45 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

46 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

47 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

48 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

were 4.75g. Additional research by Funk et al.[49,50] demonstrated that a simple head shake or plopping into a chair induces accelerations comparable to or greater than the subject incident. The available documents reported Mr. Scott worked as a chiropractor, and he testified to running 15-18 miles a week. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[51]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Scott cannot be made.

Thoracic and Lumbar Spine

There is no reason to assume that the claimed thoracic and lumbar biomechanical failures are causally related to the subject incident. The motion of Mr. Scott's thoracic and lumbar spine would have been well supported and constrained. Provided sufficient energy to overcome Mr. Scott's muscle reaction forces, his body would have moved forward relative to the Chevrolet's interior. As described previously, Mr. Scott was reported to be wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited his forward body excursion.[52] The seat belt would have locked and the lap and shoulder belts would have distributed the loads amongst his pelvis and torso, thereby reducing the motion of his body. Once again, the loading would be applied horizontally, minimizing the vertical, compressive forces on the thoracic spine. Mr. Scott's thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Mr. Scott's thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[53] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or lumbar biomechanical failures were reported. Siegmund and Williamson[54] investigated frontal impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any chronic thoracic or lumbar biomechanical failures. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[55] None of the participants reported any chronic thoracic or lumbar spine biomechanical

49 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

50 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

51 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

52 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

53 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

54 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

55 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

failures. Arbogast et al.[56] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or biomechanical failure to any participants. Research by Weiss et al.[57] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic biomechanical failures.

Studies by Rohlmann et al.[58,59,60] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[61] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[62]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Scott, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

<u>Personal Tolerance Values</u>

As noted previously, according to the available documents, Mr. Scott was a practicing chiropractor. Further, Mr. Scott played basketball, tennis, lifted weights, and ran 15-18 miles a week for exercise. These activities can produce greater movement, or stretch, to the soft tissues of Mr. Scott and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole,

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[56] Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

[57] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[58] Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

[59] Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

[60] Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

[61] Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

[62] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[63]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Scott's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Scott using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 8, 2012, Mr. Walter Scott was the seat-belted driver of a 2012 Chevrolet Cruze that was stopped in a parking area on Central Way near 3rd Street in Kirkland, Washington, when the subject Chevrolet Cruze was contacted in the front at low speed by a 2008 Mercedes-Benz GL320.
2. The severity of the subject incident was significantly below 10 miles-per-hour with an average acceleration less than 3.0g
3. The acceleration experienced by Mr. Scott was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subsequent frontal impact would tend to move Mr. Scott's body forward relative to the vehicle's interior. These motions would have been limited and well controlled by the seat structures and three point restraint system. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Scott's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Scott's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic biomechanical failures cannot be made.

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63 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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September 22, 2015

Gavin Radkey, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Pomeroy, Jane v. Thomas Pink*
ARCCA Case No.: 3271-333

Dear Mr. Radkey:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Jane Pomeroy. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on March 2, 2012, Ms. Jane Pomeroy was the seat-belted driver of a 2001 Lincoln Navigator traveling on Highway 305 North near the intersection of Day Road in Bainbridge, Washington. Mr. Thomas Pink was the driver of a 2006 Nissan Frontier traveling directly behind the Lincoln Navigator. While the Lincoln Navigator was stopped, contact was made between the front of the Nissan Frontier and the rear of the Lincoln Navigator. No airbags were deployed in either vehicle and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Sixteen (16) color photographic reproductions of the subject 2001 Lincoln Navigator
- Three (3) black and white photographic reproductions of the subject 2001 Lincoln Navigator
- Ten (10) color photographic reproductions of the incident 2006 Nissan Frontier
- Safeco Insurance Estimate of Record for the subject 2001 Lincoln Navigator [May 31, 2012]
- Jerry's Auto Rebuild Estimate of Record for the incident 2006 Nissan Frontier [May 25, 2012]
- Deposition transcript for Jane Pomeroy [April 27, 2015]
- Plaintiff Answers to Interrogatories [April 16, 2015]
- Medical Records pertaining to Jane Pomeroy
- VinLink data sheet for the subject 2001 Lincoln Navigator
- Expert AutoStats data sheets for a 2001 Lincoln Navigator
- VinLink data sheet for the incident 2006 Nissan Frontier
- Expert AutoStats data sheets for a 2006 Nissan Frontier
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as

documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Pomeroy's claims were caused by the subject incident on March 2, 2012;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2001 Lincoln Navigator;
3. Determine Ms. Pomeroy's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Pomeroy's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Pomeroy attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
  - Scoliosis

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair estimates of the subject 2001 Lincoln Navigator and the incident 2006 Nissan Frontier in association with accepted scientific methodologies. [11,12]

The repair estimate for the subject 2001 Lincoln Navigator reported damage to the rear bumper cover, which is consistent with the reviewed photographs (Figure 1). In addition, the repair documents noted prior collision damage to the driver's side fender. The photographs depicted no residual crush to the rear of the Lincoln Navigator. Ms. Pomeroy's testimony indicated she observed no damage to the bumper.

Figure 1: Reproductions of photographs of the subject 2001 Lincoln Navigator

The repair documents for the incident 2006 Nissan Frontier indicated there was damage to the front bumper and license plate bracket. The photographs depicted minor misalignment of the front bumper (Figure 2).

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 2: Reproductions of photographs of the incident 2006 Nissan Frontier

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 2001 Lincoln Navigator revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the rear of a 1998 Ford Expedition, a sister to the 2001 Lincoln Navigator, would result in significant and visibly noticeable crush across the entirety of the subject Navigator's rear structure, with a residual crush of 4 inches. This depth of crush would result in damage to rear tail light assemblies, quarter panel edges, and the entire rear bumper structure. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20]

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 PC-Crash Collision Software.

20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

The lack of significant structural crush to the entire rear of the subject Lincoln Navigator indicates a collision resulting in a Delta-V significantly below 10 miles per hour. [21,22,23,24,25,26]

Additionally, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. This empirical testing was used to perform a damage threshold speed change analysis.[27, 28] The IIHS tested several cars of the same era from the same manufacturer as the subject vehicle as well as vehicles from other manufacturers. In a five mile-per-hour rear concentrated force impact the test vehicles sustained damage to the rear bumper covers, rear reinforcement bars, frame rail extensions, trunk lids, liftgates, and rear mounting brackets among other parts in some tests. The primary damage to the subject vehicle was the rear bumper cover. Thus, because the test vehicles in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is more comparable to the severity of the subject incident and places the subject incident speed closer to the test speed of 5 miles-per-hour.

Using an acceleration pulse with the shape of a haversine and an impact duration of 200 milliseconds (ms), the peak acceleration associated with a 10 mile-per-hour impact is 4.6g and 2.3g for a 5 mile-per-hour Delta-V.[29,30,31,32] By the laws of physics, the average acceleration experienced by the subject Lincoln Navigator in which Ms. Pomeroy was seated was significantly less than 4.6g and more consistent with 2.3g.

The acceleration experienced due to gravity is 1g. This means that Ms. Pomeroy experiences 1g of loading while in a sedentary state. Therefore, Ms. Pomeroy experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [33] More

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21 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2010 Honda CR-V into 2010 Honda Civic, December 2010.

22 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

23 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

24 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

25 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

26 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

27 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers

28 Insurance Institute for Highway Safety Bumper Evaluation Crash Test Report. 2002 Ford Explorer, November 2001.

29 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

30 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

31 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

32 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

33 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Pomeroy's medical records indicated she was 64 inches in height, weighed approximately 130 lbs., and was 62 years old at the time of the subject incident. Ms. Pomeroy testified her foot was on the brake and was unaware of the incident vehicle immediately before the incident. Ms. Pomeroy testified that her head hit the headrest "two-plus times", her arms were thrown up in the air, and she turned her head to look over her right shoulder immediately after the incident.

The laws of physics dictate that when the subject Lincoln Navigator was contacted in the rear, it would have been pushed forward causing Ms. Pomeroy's seat to move forward relative to her body. This motion would result in Ms. Pomeroy moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Pomeroy's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Pomeroy was wearing the available three point restraint. As Ms. Pomeroy's body moved rearward the seat belt would retract with her body. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Pomeroy's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Pomeroy would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Pomeroy was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[34,35]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure

[34] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[35] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

<u>Cervical Spine</u>

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Lincoln Navigator would be pushed forward and Ms. Pomeroy would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2008 Ford Expedition, a sister vehicle of the Lincoln Navigator production model years 1998-2011, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 32.0 inches in the full-down position, and 33.5" in the full-up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Pomeroy revealed she would have a normal seated height of 32.3 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Pomeroy's cervical spine would have undergone only a subtle degree of the characteristic response phases.[36] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[37] The cervical loads were within physiologic limits and Ms. Pomeroy would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[38,39,40]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[41,42,43,44,45] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure

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36 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

37 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

38 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

39 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

40 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

41 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

42 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

43 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

44 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

45 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

threshold is 5g.[46] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[47,48,49,50] The available documents reported Ms. Pomeroy was capable of performing regular daily and work activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[51]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Pomeroy cannot be made.

Thoracic and Lumbar Spine

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Pomeroy is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Pomeroy's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur. Furthermore, the mechanism to induce acute scoliosis would also not be present.

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46 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

47 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

48 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

49 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

50 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

51 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[52,53,54,55] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[56] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[57,58] Ms. Pomeroy's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[59,60,61,62,63]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [64,65,66,67] Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable

52 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

53 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

54 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

55 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

56 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

57 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

58 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

59 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

60 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

61 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

62 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

63 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

64 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

65 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

66 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

67 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

to or greater than the subject incident.[68,69] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[70] According to the available documents, Ms. Pomeroy was capable of performing daily and work activities. A segmental analysis of Ms. Pomeroy demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[71,72,73]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Pomeroy, a causal link between the subject incident and claimed thoracic biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Ms. Pomeroy owned and operated a kitchen and home supply store. Further, this job required her to lift and push boxes weighing up to 75 pounds. According to Ms. Pomeroy's medical records and testimony, her hobbies included gardening, skiing, swimming, and sailing. Ms. Pomeroy also had a catering business which involved cooking and spending long hours on her feet. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Pomeroy and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[74]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Pomeroy's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure

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68 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

69 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

70 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

71 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

72 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

73 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

74 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

mechanisms, and an understanding of the unique personal tolerance level of Ms. Pomeroy using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On March 2, 2012, Ms. Jane Pomeroy was the seat-belted driver of a 2001 Lincoln Navigator that was stopped on Highway 305 N near the intersection of Day Road in Bainbridge, Washington, when the subject Lincoln Navigator was contacted in the rear at low speed by a 2006 Nissan Frontier.
2. The severity of the subject incident was significantly below 10 miles-per-hour and more consistent with 5 miles-per-hour with a peak acceleration less than 4.6g and more consistent with 2.3g.
3. The acceleration experienced by Ms. Pomeroy was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Pomeroy's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Pomeroy's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Pomeroy's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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November 17, 2015

Joshua Rosen, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 Second Avenue
Suite 500
Seattle, WA 98101

Re: *Gaines, Emancia v. Olga Bakyeva and Temple De Hirsch Sinai*
Claim No.: 743752105039
ARCCA Case No.: 3271-353

Dear Mr. Rosen:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Emancia Gaines. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on June 11, 2012, Ms. Emancia Gaines was the unbelted driver of a 2006 Scion xA parked on 3rd Avenue between Lenora and Virginia Street in Seattle, Washington. As Ms. Gaines was preparing to exit the subject Scion, a 2005 Chevrolet Express 3500 contacted the rear driver's side of the subject Scion. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Thirteen (13) color photographic reproductions of the subject 2006 Scion xA
- Ten (10) color photographic reproductions of the incident 2005 Chevrolet Express 3500
- Metro Auto Rebuild Preliminary Estimate for repairs of the subject 2006 Scion xA [August 7, 2012]
- Comsearch Estimate of Record for the subject 2006 Scion xA [October 2, 2012]
- Safeco Insurance Company Estimate of Record for the incident 2005 Chevrolet Express 3500 (listed as a 2005 Chevrolet G30) [July 11, 2012]
- Defendants' First Interrogatories and Requests for Production, *Emancia Gaines vs. Olga Bakyeva and Temple De Hirsch Sinai* [June 13, 2015]
- Deposition Transcript of Emancia Gaines, *Emancia Gaines vs. Olga Bakyeva and Temple De Hirsch Sinai* [October 21, 2015]
- Medical Records pertaining to Emancia Gaines
- VinLink data sheet for the subject 2006 Scion xA
- Expert AutoStats data sheets for a 2006 Scion xA
- VinLink data sheet for the incident 2005 Chevrolet Express 3500
- Expert AutoStats data sheets for a 2005 Chevrolet Express 3500
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Gaines claims were caused by the subject incident on June 11, 2012;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Ms. Gaines was occupying;
3. Determine Ms. Gaines's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomedical failures and determine whether the defined biomechanical failure mechanisms were created during Ms. Gaines's response to the subject incident.
5. Evaluate Ms. Gaines's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomedical failures, a causal link between the biomedical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomedical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Ms. Gaines attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the subject 2006 Scion xA and the incident 2005 Chevrolet Express 3500 in association with accepted scientific methodologies.[11,12]

The Estimate of Record for the subject Scion xA reported damage to the rear bumper cover, left side bumper support, and left quarter panel. The photographs depicted scuffs/scratches to the rear bumper cover and partially on the left rear quarter, with no residual crush (Figure 1).

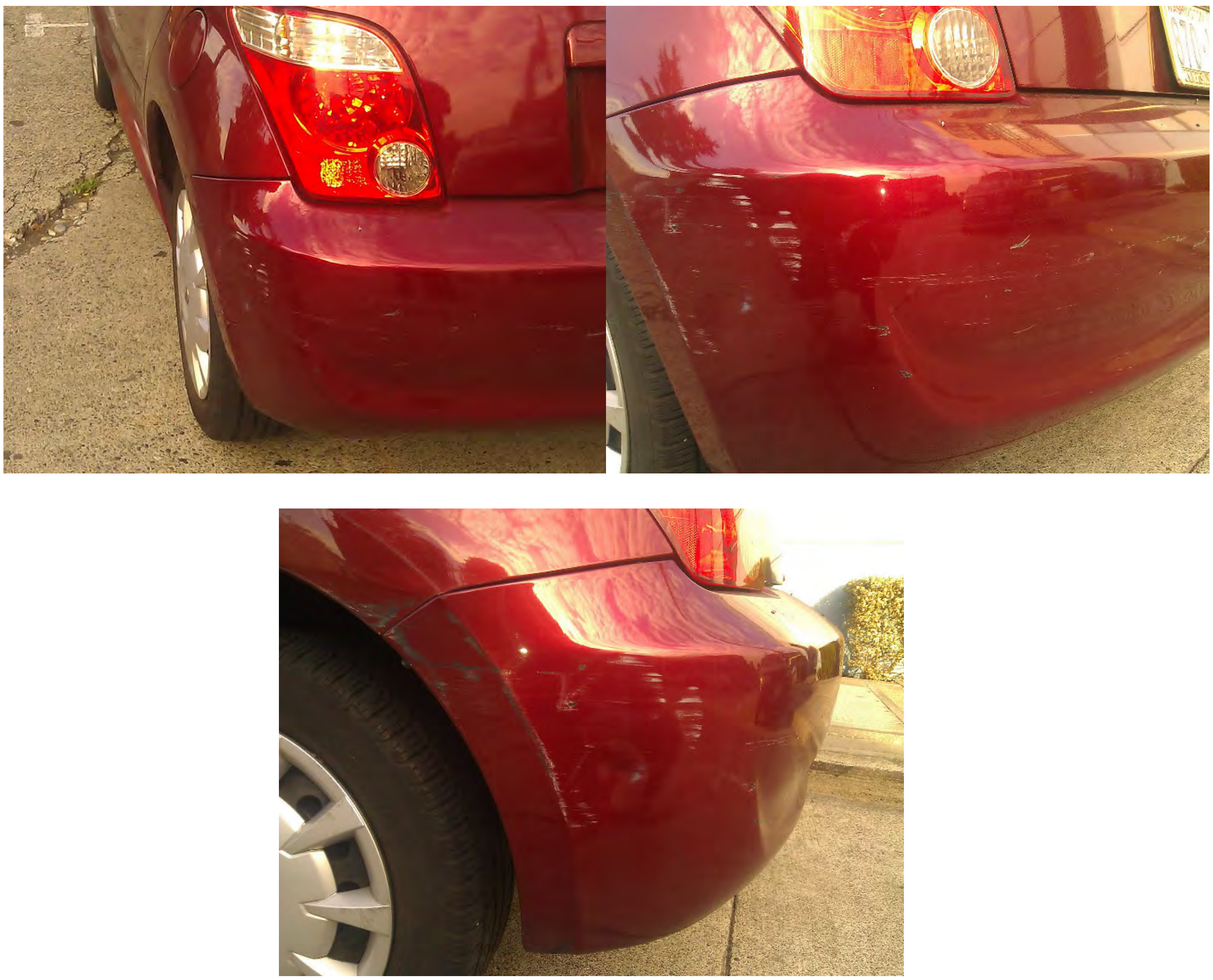

Figure 1: Reproductions of photographs of the subject 2006 Scion xA

The Estimate of Record for the incident Chevrolet Express reported damage primarily to the right side panel due to the subject incident. It was also noted that prior damage existed to the same right side panel. The reviewed photographs of the incident Chevrolet depicted minor denting and horizontal scrapes/scratches to the passenger's side panel (Figure 2). It is important to note that additional dents and scratches are depicted near the top of the passenger's side rear fender, and just below the window on the passenger's side rear panel. This damage is not consistent with the location of damage to the subject Scion, and is considered as part of the prior damage noted on the

11 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

12 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

Estimate of Record. No structural or significant metal components were indicated as damage in the repair records or in the reviewed photographs.

Figure 2: Reproductions of photographs of the incident 2005 Chevrolet Express 3500

Scientific analyses of the photographs and geometric measurements of the vehicles along with the available testimony, identified that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces. As such, the subject incident was consistent with a sideswipe event.[13] The laws of physics dictate that the lateral force exerted to the rear bumper of the subject Scion was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the incident as a result of the sideswipe event was less than 0.5g.[14] Using an acceleration pulse with the shape of a haversine and duration of 200 milliseconds,[15] the Delta-V associated with the subject incident is 1 mph. The lateral forces to the Nissan Sentra associated with the subject incident were calculated to be insignificant.

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13 Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

14 Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions, (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

15 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

ARCCA

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that Ms. Gaines experiences 1g of loading while in a sedentary state. Therefore, Ms. Gaines experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[16] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

According to the available medical records, Ms. Gaines was 29 years old, 69 inches tall, and weighed approximately 222 lbs. The records continued to describe Ms. Gaines was not wearing the available three point restraint at the time of the subject incident. Ms. Gaines testified that her seat was positioned *"all the way back",* and she felt her *"body go to the right, and I heard a thud"*. Ms. Gaines's medical records indicate she did not strike the driver's side window, but her head and upper body "whipped" to the passenger side by the impact.

The laws of physics dictate that had there been enough energy transferred to initiate motion, the sideswipe event would have caused the subject Scion to accelerate longitudinally and rightward. Scientific literature indicates that provided the low accelerations of the event, less than 1.25g, no significant occupant motion would have occurred.[17,18] ARCCA, Incorporated has conducted experiments that exposed motor vehicles to low severity contact events similar to the subject incident. These experiments included tracking the movement of human volunteers and anthropomorphic test devices (ATDs) during the testing. Results demonstrated that neither the human volunteers nor the ATDs experienced any significant motion relative to the vehicle's interior. If occupant motion were assumed to have occurred during the subject incident, the laws of physics and results from previous studies[19,20] dictate that Ms. Gaines would have tended to move *rearward and leftward*, not to the right, relative to the vehicle's interior. Any rightward motion would have been due to Ms. Gaines's own volition and not as a result of the subject incident. Further, even without wearing the seat belt restraint, the primary direction of Ms. Gaines's body would be into the seat back structure. This motion would have been controlled and supported by the friction generated at her seat bottom and the interior driver's side door components.[21] Additional support would have been provided by the seat back and head restraint. Provided the low accelerations of the subject incident, and the supports described, the bodily response of Ms. Gaines would have been limited to well within normal physiological limits.

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16 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

17 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

18 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

19 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

20 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

21 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Gaines was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomedical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomedical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

<u>Cervical Spine</u>

According to Ms. Gaines's medical records, she was diagnosed with a cervical spine sprain/strain type biomedical failure. An X-ray of her cervical spine dated October 10, 2012, identified no recent fracture or gross dislocation.

As described previously, the sideswipe event would have caused the subject Scion to accelerate longitudinally and to the right. Scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, no significant occupant motion would have occurred.[24,25] If occupant motion were assumed, Ms. Gaines would have moved rearward and leftward relative to the vehicle's interior.[26,27] This motion would have been

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22 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

23 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

24 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

25 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

26 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

27 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

supported and constrained by the seatback structure of the subject Scion. Had Ms. Gaines's body experienced enough energy to cause motion, the only general exposure for biomechanical failure of a properly seated occupant in such a minor impact is due to the relative motion of the head and neck with respect to the torso, causing a "whiplash" biomechanical failure to the neck. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat. The National Highway Traffic Safety Administration (NHTSA) conducts impact safety tests for continued performance and safety monitoring of the automotive industry. Testing for a 2004 Scion xA, production model years 2004-2007, showed the seated height of a 50th percentile male in the driver's seat was well protected and supported by the seatback components (Figure 3). [28]

Figure 3: NTHSA 50th Percentile Male ATD in 2004 Scion xA

Ms. Gaines's medical records indicated she was 69 inches tall, approximately 222 lbs., and 29 years old at the time of the subject incident. Performing an anthropometric regression of Ms. Gaines revealed she would have a normal seated height of 35.0 inches, approximately the same height as a 50th percentile male ATD, thus the seatback is tall enough to have prevented hyperextension of Ms. Gaines. Furthermore, the available documentation confirms that the head restraint was positioned behind Ms. Gaines's head.

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[29,30,31,32,33] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing

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[28] National Highway Traffic Safety Administration (2006). Safety Compliance Testing for FMVSS 214 Side Impact Protection Indicant, Report No. 214-CAL-06-02. 2006 Kia Sedona.

[29] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[30] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

[31] Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

[32] Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

[33] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[34] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [35,36,37,38] Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[39]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Gaines cannot be made.

Thoracic and Lumbar Spine

According to the available documents Ms. Gaines was diagnosed with a thoracic and lumbar sprain/strain

In this type of collision, the motion of Ms. Gaines's thoracic and lumbar spine would have been well supported and constrained. Once again, scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, no significant occupant motion would have occurred.[40,41] Primarily, Ms. Gaines would have been jostled within her seated. Provided sufficient energy to overcome Ms. Gaines's muscle reaction forces, her body would have moved rearward and leftward relative to the Scion's interior. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to Ms. Gaines's thoracic and lumbar spine. The majority of the loading would be applied in a horizontal direction to the entire torso, not axially along the spine. A mechanism would only be present if significant

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34 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

35 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

36 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

37 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

38 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

39 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

40 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

41 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to the adjacent vertebra. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine. A lack of loading to the soft and hard tissues of the thoracic spine indicates that it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur. In the absence of this acute biomechanical failure mechanism for lumbar disc failure, scientific investigations have shown that the above lumbar disc diagnoses can be the result of the normal aging process.[42,43]

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[44,45,46,47] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[48] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[49,50] Ms. Gaines's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[51,52,53,54,55]

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42 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

43 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

44 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

45 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

46 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

47 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

48 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

49 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

50 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

51 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

52 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

53 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

54 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

55 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[56,57,58,59] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[60] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[61,62] Ms. Gaines's lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[63,64,65,66,67]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Gaines, a causal link between the subject incident and claimed thoracic and lumbar spine biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Ms. Gaines was employed at the YWCA, and as a housing case manager at Plymouth Housing. Ms. Gaines testified that her regular duties included doing laundry, cleaning, mopping, moving furniture, and "taking large carts of trash" out. Ms. Gaines further testified that her hobbies included running, playing sports, lawn mowing, Frisbee, dancing,

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56 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

57 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

58 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

59 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

60 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

61 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

62 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

63 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

64 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

65 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

66 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

67 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

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and the lifting free weights (reportedly up to 50-60 lbs). Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Gaines and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[68]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Gaines's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Gaines using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On June 11, 2012, Ms. Emancia Gaines was the unbelted driver of a 2006 Scion xA that was contacted in the rear driver's side at low speed by a 2005 Chevrolet Express 3500.
2. The severity of the subject incident was consistent with a Delta-V less than 1 miles-per-hour with peak acceleration less than 0.5g for the subject 2006 Scion xA in which Ms. Gaines was seated.
3. The acceleration experienced by Ms. Gaines was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. Had the forces of the subject incident been sufficient to overcome the muscle reaction forces, Ms. Gaines's body would have moved rearward and leftward relative to the vehicle's interior. These motions would have been limited and well controlled by the driver's side door interior components, seat back, head restraint, and seat bottom friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Gaines's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Gaines's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

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[68] Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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December 1, 2015

[redacted]

[redacted]

[redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of [redacted] This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

<u>Incident Description</u>:

According to the available documents, on August 5, 2011, [redacted] was the seat belted front passenger of a 2005 Ford Explorer traveling northbound on Interstate 5 near mile marker 162 in in Seattle, Washington. [redacted] was the driver of the subject Ford Explorer. [redacted] was the driver of a 2009 GMC Sierra traveling immediately behind the subject Ford Explorer. While braking for traffic, contact was made between the front of the GMC Sierra and the rear of the Ford Explorer. Subsequently, the front of the Ford Explorer made contact with the rear of a 1996 Chevrolet Corsica. No airbags were deployed, and the incident Sierra was towed from the scene.

<u>Information Reviewed:</u>

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. E118563* [August 5, 2011]
- Thirty-five (35) color photographic reproductions of the subject 2005 Ford Explorer
- Two (2) color photographic reproductions of the incident 2009 GMC Sierra
- Allstate Insurance Company dba Northwest Auto MCO Estimate for repairs of the subject 2005 Ford Explorer [August 9, 2011]
- Ballard Collision Carstar Preliminary Supplement 1 with Summary for the subject 2005 Ford Explorer [August 25, 2011]
- Insurance Corporation of British Columbia Supplement 1 for repairs of the incident 2009 GMC Sierra [August 22, 2011]
- Insurance Corporation of British Columbia Supplement 3 for repairs of the incident 2009 GMC Sierra [August 31, 2011]
- Deposition Transcript of [redacted] [November 3, 2014]
- Deposition Transcript of [redacted] [February 20, 2015]
- Complaint for Negligence, [redacted] [July 14, 2014]
- Recorded Statement of [redacted] [September 22, 2011]
- Recorded Statement of [redacted] [September 23, 2011]
- Medical Records pertaining to [redacted]
- VinLink data sheet for the subject 2005 Ford Explorer
- Expert AutoStats data sheets for a 2005 Ford Explorer
- VinLink data sheet for the incident 2009 GMC Sierra
- Expert AutoStats data sheets for a 2009 GMC Sierra

- VinLink data sheet for the 1996 Chevrolet Corsica
- Expert AutoStats data sheets for a 1996 Chevrolet Corsica
- VinLink data sheet for the 2005 Honda Odyssey
- Expert AutoStats data sheets for a 2005 Honda Odyssey
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that [redacted] claims were caused by the subject incident on August 5, 2011;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2005 Ford Explorer;
3. Determine [redacted] kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate [redacted] personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate [redacted] attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

- Thoracic and Lumbar Spine
    - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2005 Ford Explorer and incident 2009 GMC in association with accepted scientific methodologies.[11,12]

As previously stated, it is claimed that the 2005 Ford Explorer was struck from the rear by the incident 2009 GMC Sierra resulting in the Explorer being pushed into the rear of the 1996 Chevrolet Corsica. For the front of the subject Explore, the repair documentation reported damage to the front bumper cover, license plate, lower grill, absorber, and impact bar, consistent with the photographs (Figure 1). Further, the documents indicated the front required a frame measurement. The photographs of the front of the Explorer depicted a bent license plate and partial deformation to the right side of the reinforcement bar.

Figure 1: Reproduction of the front of the subject 2005 Ford Explorer

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 2: Reproduction of the rear of the subject 2005 Ford Explorer

Regarding the rear damage to the subject Explorer, the estimate of record reported damage to the tailgate plate, tailgate glass, rear bumper and step pad, and trailer hitch, consistent with the photographs (Figure 2). Further, the documents indicated the rear required a frame measurement. The photographs of the rear depicted crush to the lower tailgate, shattered tailgate glass, bent receiver hitch apron, and scrapes to the bumper cover and tailgate.

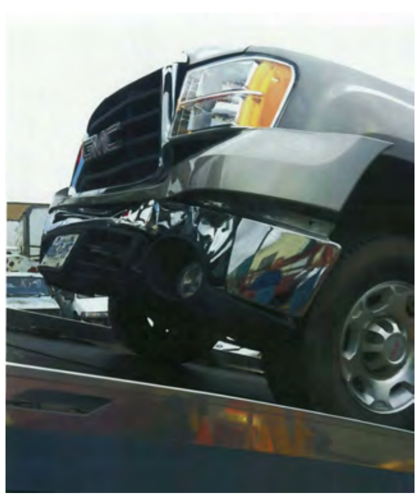

Figure 3: Reproduction of the incident 2009 GMC Sierra

The repair estimate for the incident GMC Sierra indicated replacement to the front bumper and brackets, reinforcement bar, grille, headlamp assembly, hood panel, radiator support, air conditioning condenser, and repair of the radiator and front left fender. The photographs depicted visible crush to the front bumper and grille, distortion of the left front fender, and displacement of the front bumper assembly (Figure 3).

Both impacts will be evaluated for purposes of this report. Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 2005 Ford Explorer revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the rear of a Ford Explorer would result in significant and visibly noticeable crush across the entirety of the subject Explorer's rear structure, with a residual crush of 4.5 inches, including the rear bumper assembly. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20] The lack of significant structural crush to the entire rear of the subject Ford Explorer indicates a collision resulting in a Delta-V significantly below 10 miles per hour. [21,22,23,24,25,26]

Further, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicle's bumpers and the damage incurred. The damage to the subject Ford Explorer, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[27] In a rear 5 mile-per-hour impact into a flat barrier, a Ford Explorer of the same model production year sustained damage to the bumper step pad and reinforcement bar. In the subject incident, the primary damage was to the rear tailgate, bumper cover, and receiver hitch apron. Because the bumper assembly components, which includes the receiver hitch, are substantially stiffer than the tailgate, more energy is required to damage those

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.
14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.
15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.
16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.
17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.
18 EDCRASH, Engineering Dynamics Corp.
19 PC-Crash Collision Software.
20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.
21 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2010 Honda CR-V into 2010 Honda Civic, December 2010.
22 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.
23 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.
24 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.
25 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.
26 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.
27 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

components. Therefore, it is more likely the damage to the rear of the subject Ford Explorer is more comparable with a 6.4 mile-per-hour Delta-V, accounting for restitution.

The same damage threshold analysis speed change analysis was used to evaluate the front damage to the subject Ford Explorer.[28] The IIHS tested a 2002 Ford Explorer, the production model years 2002-2005, in a 5 mile-per-hour frontal impact into a flat barrier.[29] The test Explorer sustained damage to the front bumper cover and absorber, grille, reinforcement, headlamps, and radiator support panel. The primary damage to the subject Explorer was to the front bumper cover, grille, reinforcement (impact) bar, and absorber. Thus, because the test Ford Explorer in the IIHS frontal impact test sustained similar damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident. Therefore, the subject Ford Explorer experienced a front Delta-V of 6.4 miles-per-hour, accounting for restitution.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms) for the rear impact in the worst case scenario, the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[30,31,32,33]

Regarding the frontal impact, using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.4 mile-per-hour impact is 1.9g. By the laws of physics, the average acceleration experienced by the subject Ford Explorer in which [redacted] was seated was less than 3.0g and 1.9g.

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that [redacted] experiences 1g of loading while in a sedentary state. Therefore, [redacted] experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[34] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

According to the report from [redacted], the trailer hitch included on the subject Explorer would result in significantly higher loads transferred to the occupants of the vehicle. However, there are several discrepancies with the report and its cited references. First, [redacted] includes a quote from a National Safety Commission Alert that states an increased risk of whiplash injury during a rear-end

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28 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

29 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2007 BMW 3 Series, July 2007

30 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

31 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

32 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

33 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

34 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

collision with a trailer-hitch "ball mount". The neutrality of the author of the referenced article is questionable, as he owns a company that manufactures energy absorbing safety guards for receiver hitches. Further, the referenced article by Martin is used to support the increased whiplash potential and stiffer crash test pulses. In the article Martin further references prior studies that used older vehicles than the subject vehicles. Additionally, the Martin article states, *"…considering this was a single test condition the influence of the tow-bar is not automatically applicable to other test conditions"*. It is also important to note that the subject Ford Explorer comes standard with a base tow package, which includes a receiver hitch. Therefore, the aftermarket trailer hitch does not create a stiffer rear bumper assembly than that tested in the IIHS tests referenced in this analysis. Finally, according to [redacted] testified that the impact with the subject Explorer felt *"like we were colliding with something very soft"*. This statement is consistent with an impact to the rear tailgate of the Explorer rather than a primary impact to the rear bumper assembly.

Kinematic Analysis:

[redacted] medical records indicated he was 71 inches tall, approximately 207 lbs. and 30 years old at the time of the subject incident. The medical records indicated [redacted] was surprised by the impact, and his head was turned to the left. [redacted] stated that the back of his neck hit the headrest.

The laws of physics dictate that had the subject Ford Explorer was contacted in the rear, it would have been pushed forward causing [redacted] seat to move forward relative to his body. This motion would result in [redacted] moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. [redacted] torso and pelvis would settle back into the seatback and seat bottom cushions. Any rebound would have been within the range of protection afforded by the available restraint system.

Upon impact between the subject Ford Explorer and Chevrolet Corsica, the laws of physics dictate the Ford would have been decelerated longitudinally. Had the forces generated during this interaction been sufficient to overcome the muscle reaction forces of [redacted] his body would have moved primarily forward relative to the Ford's interior. The three-point restraint that the records reported [redacted] was wearing would have locked when the vehicle accelerations exceeded 0.7g.[35] The seat belt would support and limit his body excursion. Friction generated at the seat bottom of [redacted] as well as the passive muscle resistance of his arms would have acted in conjunction with his three-point restraint to limit body motion. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of [redacted] would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to [redacted] was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there

35 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[36,37]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

According to the medical records, [redacted] was diagnosed with a cervical sprain/strain. There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Ford Explorer would be pushed forward and [redacted] would have moved rearward relative to the vehicle, until his motion was stopped by the seatback and seat bottom. Examination of an exemplar Ford Explorer of the same model production years revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 30.0 inches in the full down position, and 32.25 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of [redacted] revealed he would have a normal seated height of 35.3 inches. Thus, had the low vehicle accelerations been sufficient to cause motion of [redacted] head and cervical spine, the seatback and headrest support during the subject incident designate that [redacted] cervical spine would have undergone only a subtle degree of the characteristic response phases.[38] The load would have been applied predominantly horizontal to his cervical spine and minimized relevant cervical loads.[39] The cervical loads were within physiologic limits and [redacted] would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[40,41,42]

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36 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

37 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

38 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

39 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

40 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

41 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

42 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

Several researchers have conducted rear impact studies involving human volunteers with accelerations at levels comparable to and greater than that of the subject incident.[43,44,45,46,47] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[48] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

In the frontal impact, if motion is produced in the subject vehicle, the Ford Explorer would be pushed backward and [redacted] would have moved forward relative to the vehicle, until his motion was stopped by the lap and shoulder restraints. The seat belt would have locked and the lap and shoulder belts would have distributed the loads amongst his pelvis and torso, thereby reducing the motion of his body and preventing his head from contacting frontal interior vehicle structures during the subject incident. [redacted] cervical spine would have been subjected to a controlled degree of flexion during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact.[49] A kinematic analysis of [redacted] response to the subject incident demonstrated that his overall head motion would have been relatively minimal.[50,51] Frontal impact research involving human volunteers demonstrated that at severity levels comparable to the subject incident, head motion was predominately self-limiting.[52] As a result, [redacted] cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[53]

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43 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

44 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

45 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

46 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

47 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

48 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

49 Mertz, H.J., and Patrick, L.M., (1971). Strength and Response of the Human Neck (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

50 Araszewski, M., Roenitz, E., and Toor, A., (1999). Maximum Head Displacement of Vehicle Occupants Restrained by Lap and Torso Belts in Frontal Impacts (SAE 1999-01-0443). Warrendale, PA, Society of Automotive Engineers.

51 Happer, A.J., Hughes, M.C., Simeonovic, G.P., (2004). Occupant Displacement Model for Restrained Adults in Vehicle Frontal Impacts (SAE 2004-01-1198). Warrendale, PA, Society of Automotive Engineers.

52 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

53 Mertz, H.J. Jr. and Patrick, L.M. (1967). Investigation of the Kinematics and Kinetics of Whiplash (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

Numerous peer-reviewed and generally accepted investigations support these conclusions and have evaluated the human response to frontal impact accelerations utilizing human volunteers.[54,55] The Delta-V of the striking vehicle was comparable to or greater to that associated with the subject incident, and no chronic cervical biomechanical failures were reported. Several researchers have used cadavers to assess cervical spine biomechanical failure potential during frontal impacts. Results have demonstrated that the accelerations necessary to cause chronic cervical biomechanical failure are greater than that associated with the subject incident.[56,57] Specifically, studies performed by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[58] None of the participants reported any chronic cervical biomechanical failures. Additional human volunteer testing subjected participants to frontal impacts between 3g and 15g without any permanent physiological changes to their cervical spine and only minor neck stiffness to any participants.[59,60]

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Ng et al.,[61,62] measured accelerations of the head and spinal structures during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Additional research by Funk et al.[63,64] demonstrated that a simple head shake or plopping into a chair induces accelerations comparable to or greater than the subject incident. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[65]

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable or greater than the subject incident. More dynamic activities such as a vertical leap

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54 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

55 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

56 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

57 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

58 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

59 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

60 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

61 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

62 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

63 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

64 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

65 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

produce even higher peak head accelerations, up to 4.75g. [66,67,68,69] The available documents reported [redacted] was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[70]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of [redacted] cannot be made.

Thoracic and Lumbar Spine

There is no reason to assume that the claimed thoracic and lumbar biomechanical failures are causally related to the subject incident. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

During an event such as the subject incident, the thoracic and lumbar spine of [redacted] is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of [redacted] horacic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[71,72,73,74] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and

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66 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

67 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

68 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

69 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

70 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

71 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

72 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

73 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

74 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[75] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[76,7][redacted]thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[78,79,80,81,82]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable or greater than those resulting from subject incident.[83,84,85,86] Further studies lumbar accelerations during activities of daily living and found accelerations for activities such as sitting, walking, and jumping off a step to be comparable or greater than the subject incident.[87,88] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[89] According to the available documents, [redacted]. [redacted] was capable of performing daily activities. A segmental analysis of [redacted] demonstrated that

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75 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

76 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

77 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

78 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

79 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

80 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

81 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

82 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

83 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

84 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

85 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

86 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

87 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

88 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

89 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

as he lifted objects during daily tasks, the forces applied to his lower spine would have been comparable to or greater than those during the subject incident.[90,91,92]

Due to the frontal impact, the motion of [redacted] thoracic and lumbar spine would have been well supported and constrained. Provided sufficient energy to overcome [redacted] muscle reaction forces, his body would have moved forward relative to the Ford's interior. As described previously, [redacted] was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited his forward body excursion.[93] The seat belt would have locked and the lap and shoulder belts would have distributed the loads amongst his pelvis and torso, thereby reducing the motion of his body. Once again, the loading would be applied horizontally, minimizing the vertical, compressive forces on the thoracic and lumbar spine. [redacted] thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of [redacted] thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[94] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or thoracic and lumbar biomechanical failures were reported. Siegmund and Williamson[95] investigated frontal impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any chronic thoracic or thoracic and lumbar biomechanical failures. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[96] None of the participants reported any chronic thoracic or thoracic and lumbar spine biomechanical failures. Arbogast et al.[97] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or biomechanical failure to any participants. Research by Weiss et al.[98] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic biomechanical failures.

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90 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

91 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

92 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

93 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

94 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

95 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

96 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

97 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

98 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

Studies by Rohlmann et al.[99,100,101] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable or greater than those resulting from subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[102] Additionally, Ng, et al, studied thoracic and lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[103]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event create forces that exceeded the personal tolerance limits of [redacted], a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, [redacted] was formerly employed as a firefighter. He practiced jui-jitsu, and was a self-reportedly strong swimmer, competing in several competitions in Australia.. These activities can produce greater movement, or stretch, to the soft tissues of [redacted] and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[104]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between [redacted] reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of

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99 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

100 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

101 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

102 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

103 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

104 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

the unique personal tolerance level of [redacted] using peer-reviewed and generally-accepted methodologies.

<u>Conclusions:</u>

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On August 5, 2011, [redacted] was the seat belted front passenger of a 2005 Ford Explorer traveling on Interstate 5 in Seattle, Washington. Contact occurred between the front of the incident 2009 GMC Sierra and rear of the subject Ford Explorer. Subsequently, the Ford Explorer was pushed forward resulting in contact between the front of the subject Ford and rear of the 1996 Chevrolet Corsica.

2. The severity of the rear impact during the subject incident was significantly below 10 miles-per-hour with an average acceleration less than 3.0g

3. The severity of the frontal impact during the subject incident was significantly below 6.4 miles-per-hour with a peak acceleration less than 1.9g

4. The acceleration experienced by [redacted] was within the limits of human tolerance and comparable to that experienced during various daily activities.

5. The forces applied to the subject vehicle during the subject incident would tend to move the [redacted] body back toward the seatback structures. The forces applied to the subject vehicle during the subsequent frontal impact would tend to move the [redacted] body forward relative to the vehicle's interior. These motions would have been limited and well controlled by the seat structures and three point restraint system. All motions would be well within normal movement limits.

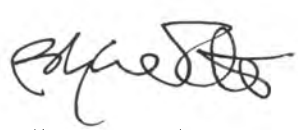
6. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

7. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,



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December 11, 2015

Mark Dietzler, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Lear, Douglas & Joie v. Edward & Hea Ma*
ARCCA Case No.: 2107-761

Dear Mr. Dietzler:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Douglas and Joie Lear. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on March 17, 2010, Mr. Douglas Lear was the driver of a 2007 Honda Odyssey traveling eastbound on Washington Boulevard SW in Lakewood, Washington. Ms. Joie Lear was the left middle passenger of the Honda Odyssey. Ms. Hea Ma was the driver of a 2004 Kia Sedona traveling directly behind the Honda. The available documents indicated the subject Honda Odyssey stopped for traffic near the intersection with 83rd Avenue SW when contact occurred between the front of the incident Kia Sedona and the rear of the incident Honda Odyssey. No airbags were deployed in either vehicle and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. E046028
- Eight (8) color photographic reproductions of the subject 2007 Honda Odyssey
- Nine (9) grayscale photographic reproductions of the subject 2007 Honda Odyssey
- Seven (7) color photographic reproductions of the subject 2004 Kia Sedona
- Estimate of Record for the subject 2007 Honda Odyssey [March 22, 2010]
- Supplement of Record 1 with Summary for the subject 2007 Honda Odyssey [March 24, 2010]
- Claim Summary for the subject 2007 Honda Odyssey [March 22, 2010]
- Claim Summary for the subject 2007 Honda Odyssey [March 24, 2010]
- Plaintiff's *First Response* to Defendant's First Set of Interrogatories and Requests for Production of Documents to Plaintiff Douglas E. Lear, *Douglas E. Lear and Joie L. Lear vs. Edward Ma and Hea Ma*
- Plaintiff's *First Response* to Defendant's First Set of Interrogatories and Requests for Production of Documents to Plaintiff Joie L. Lear, *Douglas E. Lear and Joie L. Lear vs. Edward Ma and Hea Ma*
- Deposition Transcript of Douglas E. Lear [August 8, 2013]
- Deposition Transcript of Joie L. Lear [August 8, 2013]
- Deposition Transcript of Hea Wha Ma [August 8, 2013]
- Medical Records pertaining to Douglas Lear
- Medical Records pertaining to Joie Lear
- VinLink data sheet for the subject 2007 Honda Odyssey

- Expert AutoStats data sheets for a 2007 Honda Odyssey
- VinLink data sheet for the incident 2004 Kia Sedona
- Expert AutoStats data sheets for a 2004 Kia Sedona
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Mr. and Mrs. Lear claim were caused by the subject incident on March 17, 2010;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2007 Honda Odyssey;
3. Determine Mr. and Mrs. Lear's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. and Mrs. Lear's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and their reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

Biomechanical Failure Summary:

The medical records and other available documents indicated Mr. Lear attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain
  - C5-6 small central protrusion
  - C6-7 broader based shallow protrusion with annular fissuring
- Thoracic and Lumbar Spine
  - Sprain/strain
  - Small broad based L5-S1 central protrusion
  - Tiny T11-12 broad based central protrusion
  - Tiny L4-5 broad based right foraminal far lateral protrusion

The medical records and other available documents indicated Mrs. Lear attributes the following biomechanical failures to the subject incident:

- Lumbar Spine
  - Sprain/strain
  - Mild broad based L4-5 central protrusion with associated annular fissure
  - Small L5-S1 central herniation with mild superior extrusion. Additional minimal diffuse bulge

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions and repair estimates of the subject 2007 Honda Odyssey and incident 2004 Kia Sedona in association with accepted scientific methodologies. [11,12]

The repair documents for the subject Honda reported damage primarily to the rear bumper cover and rear backup sensor due to the subject incident. The reviewed photographs of the subject Honda depicted the rear backup sensors slightly protruding or unseated from the rear bumper cover (Figure 1). There was no visible crush/indentation to the rear bumper structures as the rear step pad and bumper cover remained in proper alignment.

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 2007 Honda Odyssey

The reviewed photographs of the incident Kia depicted a broken front license plate bracket along with scuffing to the front bumper cover (Figure 2). The front bumper cover remained in proper alignment with the fender, hood, headlights, and grille along with displaying no visible signs of crush to the front bumper components.

Figure 2: Reproductions of photographs of the subject 2004 Kia Sedona

The damage to the subject 2007 Honda Odyssey defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13,14] The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested a 2008 Honda Odyssey [15] in a 6.2 mile-per-hour rear full-overlap impact. During the IIHS rear impact the test Honda Odyssey sustained damage to the inner tailgate shell, rear body floor, tailgate shell, rear bumper, and rear bumper cover. Specifically, the test results noted *"in addition to bumper cover and reinforcement damage, the rear body panel was buckled around the sidemember ends"* and *"the rear bumper cover vertically loaded the tailgate, rolling the lower edge"*. The primary damage to the subject Honda Odyssey was to the rear bumper cover and rear backup sensors. Thus, because the test Honda in the IIHS test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident consistent with an impact less than 6.2 miles-per-hour for the subject Honda Odyssey. Accounting for the coefficient of restitution, the subject incident resulted in a Delta-V significantly below 8.0 miles-per-hour for the subject Honda Odyssey. Additionally, the above analysis is consistent with an energy crush analysis to the rear of a 2007 Honda Odyssey and IIHS low-speed crash test results for a Kia Sedona. [16,17,18,19,20]

Review of the vehicle damage, incident data, published literature, scientific analyses and my experience indicates an incident resulting in a Delta-V significantly below 8.0 miles-per-hour for the subject Honda. Using an acceleration pulse with the shape of a haversine and an impact

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13 Siegmund, G.P., et al., (1996). U*sing Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*. (No. 960887). SAE Technical Paper.

14 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

15 Insurance Institute for Highway Safety Bumper Evaluation Crash Test Report. 2008 Honda Odyssey, December 2007.

16 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

17 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

18 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

19 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

20 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

duration of 150 milliseconds (ms), the average acceleration associated with an 8.0 mile-per-hour impact is 2.4g.[21,22,23,24] By the laws of physics, the average acceleration experienced by the subject Honda Odyssey in which Mr. and Mrs. Lear were seated was less than 2.4g.

The acceleration experienced due to gravity is 1g, which means that Mr. and Mrs. Lear experience 1g of loading while in a sedentary state. Therefore, Mr. and Mrs. Lear experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[25] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Mr. Lear testified he was wearing the available three point restraint during the subject incident. He testified that prior to the impact he was aware of the impending collision with his hands on the steering wheel and foot on the brake. He continued to describe that his body moved forward and back due to the collision.

Mrs. Lear testified she was wearing the available three point restraint during the subject incident. She continued to describe that she was aware of the impending collision and had tensed her whole body to brace for the impact. She testified she felt the seat catch her from the impact.

The laws of physics dictate that when contact occurred to the rear of the subject Honda Odyssey, the vehicle would have been pushed forward causing Mr. and Mrs. Lear's seats to move forward relative to their bodies. This motion would result in Mr. and Mrs. Lear moving rearward relative to the interior of the subject vehicle and their bodies, specifically their torso and pelvis, would load into the seatback structures. The low accelerations resulting from the subject incident would have caused little, or no, forward rebound of Mr. and Mrs. Lear's bodies away from the seatbacks.[26,27] The low accelerations in the subject incident and the restraint provided by the

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21 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

22 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

23 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

24 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

25 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

26 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

27 Comments on Docket 89-20, Notice 1 Concerning Standards 207, 208 and 209, Mercedes-Benz of North America, Inc., December 7, 1989.

seatback and seat belt system, then, were such that any motion of the occupants would have been limited to well within the range of normal physiological limits.[28]

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. and Mrs. Lear was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link their reported biomechanical failures and the subject incident.[29,30]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

A cervical MRI, dated September 21, 2010, revealed Mr. Lear had findings consistent with a C5-6 small central protrusion and C6-7 broader based shallow protrusion with annular fissuring along with degenerative disc disease with mild loss of height and desiccation at the C4-7 levels.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat and axial compression of the cervical spine. Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination

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[28] Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

[29] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[30] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[31] In the absence of this acute biomechanical failure mechanism for cervical disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[32,33]

In a rear impact that produces motion of the subject vehicle, the Honda Odyssey would be pushed forward and Mr. Lear would have moved rearward relative to the vehicle, until his motion was stopped by the seatback and seat bottom. Examination of an exemplar 2006 Honda Odyssey, production model years 2005-2010, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 30.75 inches in the full down position and 32.75 inches in the full up position. Further, under the load of an occupant the seat bottom cushion will compress approximately two inches. Performing an anthropometric regression of Mr. Lear (Height: 78", Weight: 242 lbs., Age: 37) revealed he would have a normal seated height of 38.1 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Mr. Lear's cervical spine would have undergone only a subtle degree of the characteristic response phases.[34,35] The load would have been applied predominantly horizontal to his cervical spine and minimized relevant cervical loads.[36] Additionally, there would be no significant compressive forces within or to Mr. Lear's cervical spine during the subject incident. The cervical loads were within physiologic limits and Mr. Lear would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[37,38,39]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[40,41,42,43,44] The test subjects

31 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.
32 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.
33 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.
34 National Highway Traffic Safety Administration (2001). "Safety Compliance Testing for FMVSS 301 Fuel System Integrity." 2001 Kia Rio.
35 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.
36 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.
37 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.
38 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.
39 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.
40 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
41 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.
42 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.
43 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.
44 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[45] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[46,47,48,49] Mr. Lear testified he was capable of performing regular daily activities along with activities such as boating, motor sports, hiking, and coaching his children's sports teams. Research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[50]

Further, Maiman et al.[51] subjected human cadaveric cervical spines to flexion-compression loading, which demonstrated the average force to failure was 802 pounds-force. Additional testing found that the average force to failure of the human cervical spine under pure compressive loading was 679 to 1,081 pounds-force. [52,53] Results from the Duma investigation found that cervical intervertebral disc failure was only observed in association with bony vertebral body fracture. Based in part on these studies, the federal government has mandated that 899 pounds-force be the failure tolerance value for compressive force on the cervical spine.[54,55]

45 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

46 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

47 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

48 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

49 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

50 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

51 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

52 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

53 Duma, S.M., Kemper, A.R., and Porta, D.J. (2008). "Biomechanical Response of the Human Cervical Spine." *Biomedical Sciences Instrumentation* 44: 135-140.

54 Seiffert, U., and Wech, L. (2003). Automotive Safety Handbook. Warrendale, PA, Society of Automotive Engineers.

55 National Highway Traffic Safety Association, Department of Transportation. (2008). Code of Federal Regulations Title 49, Volume 6, Part 571 Federal Motor Vehicle Safety Standards, Standard No. 208.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces and biomechanical failure mechanisms that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Lear cannot be made.

Thoracic and Lumbar Spine

A lumbar MRI, dated June 24, 2010, revealed Mr. Lear had findings consistent with a small broad based L5-S1 central protrusion, tiny T11-12 broad based central protrusion, and tiny L4-5 broad based right foraminal far lateral protrusion.

A lumbar operative report, dated September 18, 2012, revealed Mrs. Lear had findings consistent with a L4-5 disc that was thick and quite mobile. Further, the report noted initially there was almost complete collapse of the L5-S1 disc after distraction across the L4-5 segment and loose posterior elements of L5 were removed and osteophytes at S1 were removed.

A lumbar MRI, dated May 22, 2012, revealed Mrs. Lear had findings consistent with L4-5 intradiscal contrast, partial thickness inner annular tearing on the left side along with minor bulging visible. Further, the report noted L5-S1 posterior disc margin shows bulging, bilateral pars defect in L5 associated with disc space narrowing and gaseous degenerative changes with approximately 5mm spondylolisthesis.

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[56] In the absence of this acute biomechanical failure mechanism for lumbar disc failure, scientific investigations have shown that the above lumbar disc diagnoses can be the result of the normal aging process.[57,58] The primary mechanism for this type of biomechanical failure occurs when a sudden application of a compressive force with associated bending that exceeds the limits of the disc tissue strength. [59,60]

During the subject incident, the thoracic and lumbar spines of Mr. and Mrs. Lear were well supported by the seats and seatbacks. This support prevents biomechanical failure motions or loading of the thoracic and lumbar spines of Mr. and Mrs. Lear. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms

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56 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

57 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

58 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

59 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

60 Adams, M.A., and Hutton, W.C. (1982). "Prolapsed Intervertebral Disc: A Hyperflexion Injury." Spine. 7: 184-191.

are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The majority of the loading would be applied in a horizontal direction to the entire torso, not a compressive/axial load, which would be as a whole unit loading into the seatback. A mechanism would only be present if significant relative motion of the individual vertebrae existed in the subject incident. For example, if one vertebra was moving in a different direction relative to its neighbor. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[61,62,63,64] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[65] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[66,67] Mr. and Mrs. Lear's thoracic and lumbar spines would not have been exposed to any loading or motion outside of the range of their personal tolerance levels.[68,69,70,71,72]

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[61] Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

[62] Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

[63] Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

[64] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[65] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

[66] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[67] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

[68] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[69] Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

[70] Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

[71] Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

[72] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [73,74,75,76] Mr. Lear testified he was capable of performing regular daily activities along with activities such as boating, motor sports, hiking, and coaching his children's sports teams. Mrs. Lear testified she was capable of performing regular daily activities along with activities such as hiking, cleaning the house, boating, and working. Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[77,78] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[79] A segmental analysis of Mr. and Mrs. Lear demonstrated that as they lifted objects during daily tasks, the forces applied to their lumbar spines would have been comparable to or greater than those during the subject incident.[80,81,82]

Additionally, Kavcic et al investigated lumbar compression and muscle forces generated during stabilization exercises and found lumbar compressive loads averaging around 450 pounds.[83] Additionally, ARCCA has investigated the compressive lumbar force in a 50th Percentile Hybrid III when plopped into a chair, which is consistent with the previous studies. When dropped from a height of approximately 3 and 10 inches, the compressive force on the lumbar spine equated to an acceleration of approximately 1.6g to 4.7g, respectively.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces and biomechanical failure mechanisms that exceeded the limits of human tolerance, a causal link between the subject incident and the reported thoracic and lumbar spine biomechanical failures of Mr. and Mrs. Lear cannot be made.

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73 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

74 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

75 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

76 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

77 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

78 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

79 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

80 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

81 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

82 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

83 Kavcic, N. et al (2004). "Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises." SPINE, Vol. 29(20): 2319-2329.

Personal Tolerance Values

According to the available documents, Mr. Lear worked as a vocational counselor. Additionally, the documents reported he was capable of coaching his children's sports teams, hiking, boating, and many other activities. Mrs. Lear worked as a part-time vocational counselor. Additionally, she participated in activities such as boating, cleaning house, laundry, hiking, and caring for her children. These activities can produce greater movement, or stretch, to the soft tissues of Mr. and Mrs. Lear and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[84]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. and Mrs. Lear's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. and Mrs. Lear using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On March 17, 2010, Mr. Douglas Lear was the seat-belted driver of a 2007 Honda Odyssey traveling along Washington Boulevard SW in Lakewood, Washington, when it was contacted from behind by a 2004 Kia Sedona at a low speed. Mrs. Joie Lear was the seat-belted left middle passenger of the 2007 Honda Odyssey.

2. The severity of the subject incident was significantly below 8.0 miles-per-hour with an average acceleration less than 2.4g.

3. The acceleration experienced by Mr. and Mrs. Lear was within the limits of human tolerance and comparable to that experienced during various daily activities.

4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. and Mrs. Lear's bodies back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Lear's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

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84 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper.

6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. and Mrs. Lear's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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January 5, 2016

Alina Polyak, Esquire
Moore & Davis
19909 120th Avenue NE, Suite 201
Bothell, WA 98011

Re: *Pak-Byeon, Hanna v. Lisa and John Cassidy & USAA*
ARCCA Case No.: 1860-257

Dear Ms. Polyak:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Hanna Pak-Byeon. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

The available documents reported, on January 10, 2014, Ms. Hanna Pak-Byeon was the seat-belted driver of a 2005 Dodge Stratus traveling on a roadway in Kirkland, Washington. Ms. Lisa Cassidy was the driver of a 2008 Honda Ridgeline traveling directly behind the Dodge. The available documents indicated that as the Dodge was stopped for traffic, contact occurred between the front of the incident Honda and the rear of the subject Dodge. No airbags were deployed and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Fifteen (15) color photographic reproductions of the subject 2005 Dodge Stratus
- Three (3) color photographic reproductions of the incident 2008 Honda Ridgeline
- Progressive Casualty Insurance Company Repair Estimate for the subject 2005 Dodge Stratus, January 23, 2014
- Plaintiff Hanna Pak-Byeon Answers to Defendants' MAR Interrogatories to Plaintiff General Objections, November 16, 2015
- Plaintiff's Statement of Damages, October 7, 2015
- First Amended Complaint for Damages, September 3, 2015
- Medical Records pertaining to Hanna Pak-Byeon
- VinLink data sheet for the subject 2005 Dodge Stratus
- Expert AutoStats data sheets for a 2005 Dodge Stratus
- Expert AutoStats data sheets for a 2008 Honda Ridgeline
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

1. Identify the biomechanical failures that Ms. Pak-Byeon claims were caused by the subject incident on January 10, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2005 Dodge Stratus;
3. Determine Ms. Pak-Byeon's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Pak-Byeon's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The medical records and other available documents indicated Ms. Pak-Byeon attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic, Lumbar, and Lumbosacral Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions and repair estimates of the subject 2005 Dodge Stratus and incident 2008 Honda Ridgeline in association with accepted scientific methodologies. [11,12]

The repair documents for the subject Dodge reported damage primarily to the rear bumper cover due to the subject incident. The reviewed photographs of the subject Dodge depicted an impression and paint scuffing to the rear bumper cover more toward the passenger side of the

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8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

vehicle (Figure 1). Overall, the photographs depicted no misalignment of the rear bumper cover with the quarter panels, tail lights, or trunk lid. The documents indicated the subject Dodge was not repaired and the damage was very minor.

Figure 1: Reproductions of photographs of the subject 2005 Dodge Stratus

The reviewed photographs of the incident Honda depicted scratches and scuffs to the front bumper cover skewed toward the passenger side (Figure 2). Overall, the front bumper cover remained in proper alignment with the grille, headlights, and hood.

Figure 2: Reproductions of photographs of the incident 2008 Honda Ridgeline

The damage to the subject 2005 Dodge Stratus defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13,14] The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested a 2001 Dodge Stratus [15], model range 2001-2006, in a 5 mile-per-hour rear full-overlap impact. During the IIHS rear impact the test Dodge Stratus sustained damage to the rear bumper reinforcement along with the left and right rear bumper mounting brackets. The primary damage to the subject Dodge was to the rear bumper cover. Thus, because the test Dodge Stratus in the IIHS test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident below 5.0 miles-per-hour for the subject Dodge Stratus. Accounting for the coefficient of restitution, the subject incident resulted in a Delta-V less than 6.5 miles-per-hour for the subject Dodge Stratus. Additionally, the above analysis is consistent with other IIHS low-speed testing of a Dodge Stratus.[16]

Review of the vehicle damage, incident data, published literature, scientific analyses and my experience indicates an incident resulting in a Delta-V below 6.5 miles-per-hour for the subject Dodge Stratus. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.5 mile-per-hour impact is 2.0g.[17,18,19,20] By the laws of physics, the average acceleration experienced by the subject Dodge in which Ms. Pak-Byeon was seated was less than 2.0g.

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13 Siegmund, G.P., et al., (1996). U*sing Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*. (No. 960887). SAE Technical Paper.

14 Happer, A.J., Hughes, M.C., Peck, M.D., et al., (2003). *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

15 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2001 Dodge Stratus, January 2001.

16 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2004 Jeep Grand Cherokee and 2004 Dodge Stratus, September 2004.

17 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

18 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

19 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

The acceleration experienced due to gravity is 1g, which means that Ms. Pak-Byeon experiences 1g of loading while in a sedentary state. Therefore, Ms. Pak-Byeon experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[21] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

The available documents indicated Ms. Pak-Byeon was facing forward and unaware of the impending collision. Due to the impact, the documents indicated Ms. Pak-Byeon did not experience body contact with the interior of the vehicle. The laws of physics dictate that when contact occurred to the rear of the subject Dodge Stratus, the vehicle would have been pushed forward causing Ms. Pak-Byeon's seat to move forward relative to her body. This rearward motion would result in Ms. Pak-Byeon moving rearward relative to the interior of the subject vehicle and her body, specifically her entire torso and pelvis, would load into the seatback structures. The available documents reported Ms. Pak-Byeon was wearing the three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Pak-Byeon would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Pak-Byeon was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?

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[20] Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

[21] Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

[22] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[23] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident.

The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat. In a rear impact that produces motion of the subject vehicle, the Dodge Stratus would be pushed forward and Ms. Pak-Byeon would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Performing an anthropometric regression (25 years old, 62 inches tall, and ~120 lbs. in weight) of Ms. Pak-Byeon revealed she would have a normal seated height of 31.9 inches. Under the load of an occupant the seat bottom cushion will compress approximately two inches. Examination of an exemplar 2001 Dodge Stratus revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.0 inches in the full down position and 33.0 inches in the full up position. In addition, the available documents reported Ms. Pak-Byeon's headrest was 2 inches above her head. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Pak-Byeon's cervical spine would have undergone only a subtle degree of the characteristic response phases. [24,25] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[26] The cervical loads were within physiologic limits and Ms. Pak-Byeon would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[27,28,29]

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[24] National Highway Traffic Safety Administration (2001). "Safety Compliance Testing for FMVSS 301 Fuel System Integrity." 2001 Kia Rio.

[25] Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

[26] Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

[27] Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

[28] Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

[29] Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

Several researchers have conducted human volunteer rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[30,31,32,33,34] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[35] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

Ms. Pak-Byeon's records indicated that she was capable of performing normal daily activities along with recreational activities. The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[36,37,38,39] Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[40]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Pak-Byeon cannot be made.

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30 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

31 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

32 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

33 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

34 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

35 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

36 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

37 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

38 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

39 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

40 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Thoracic, Lumbar, and Lumbosacral Spine

During the subject incident, the thoracic, lumbar, and lumbosacral spine of Ms. Pak-Byeon was well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Pak-Byeon's thoracic, lumbar, and lumbosacral spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic, lumbar, and lumbosacral spine. The lack of relative motion between individual vertebrae would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic, lumbar, and lumbosacral spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[41,42,43,44] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[45] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[46,47] Ms. Pak-Byeon's thoracic, lumbar, and lumbosacral spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[48,49,50,51,52]

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41 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

42 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

43 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

44 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

45 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

46 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

47 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

48 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

49 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

50 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

51 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

52 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [53,54,55,56] Ms. Pak-Byeon's documents reported she was capable of performing daily and recreational activities. Additionally, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[57,58] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[59]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic, lumbar, and lumbosacral spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic, lumbar, and lumbosacral spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Pak-Byeon, a causal link between the subject incident and claimed thoracic, lumbar, and lumbosacral biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Ms. Pak-Byeon worked as a nanny caring for four small children approximately 40 hours per week. Additionally, Ms. Pak-Byeon participated in activates such as hiking and running 5k races. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Pak-Byeon and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[60]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were

53 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

54 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

55 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

56 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

57 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

58 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

59 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

60 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper.

not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Pak-Byeon's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Pak-Byeon using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On January 10, 2014, Ms. Hanna Pak-Byeon was the seat-belted driver of a 2005 Dodge Stratus that was stopped for traffic when contact occurred between the front of a 2008 Honda Ridgeline and the rear of the subject Dodge.
2. The severity of the subject incident was below 6.5 miles-per-hour with an average acceleration less than 2.0g.
3. The acceleration experienced by Ms. Pak-Byeon was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Pak-Byeon's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Pak-Byeon's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Pak-Byeon's claimed thoracic, lumbar, and lumbosacral biomechanical failures. As such, a causal relationship between the subject incident and the thoracic, lumbar, and lumbosacral biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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February 5, 2016

Alina Polyak, Esquire
Moore & Davis
19909 120th Avenue NE, Suite 201
Bothell, WA 98011

Re: *Pak-Byeon, Hanna v. Lisa and John Cassidy & USAA*
ARCCA Case No.: 1860-257

Dear Ms. Polyak:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Hanna Pak-Byeon. This letter is meant to supplement my report of January 5, 2016 regarding Hanna Pak-Byeon. Since that time, I have had the opportunity to review and evaluate additional documents related to the subject incident on January 10, 2014. Furthermore, the additional documents do not change my opinion of my previous analysis:

<u>Additional Information Reviewed</u>:

In the course of my analysis regarding Hanna Pak-Byeon, I reviewed the additional following materials:

- Deposition Transcript of Hanna Pak Byeon, December 14, 2015

<u>Discussion</u>:

Ms. Pak-Byeon testified she was seated with both hands on the steering wheel and her foot on the brake. Additionally, she testified that her body was thrown forward and she was really close to the steering wheel due to the motion. As stated in my report on January 5, 2016, the laws of physics dictate that when contact occurred to the rear of the subject Dodge Stratus, the vehicle would have been pushed forward, causing Ms. Pak-Byeon's seat to move forward relative to her body. This rearward motion would result in Ms. Pak-Byeon moving rearward relative to the interior of the subject vehicle and her body, specifically her entire torso and pelvis, would load into the seatback structures. The available documents reported Ms. Pak-Byeon was wearing the three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system.

Additionally, Ms. Pak-Byeon testified that her only complaints from the subject incident on January 10, 2014, were to her neck and shoulders.

The previous report dated January 5, 2016 did not address Ms. Pak-Byeon's shoulders. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and

repetitive microtrauma to the abducted shoulder joint.[1,2,3] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

During the subject incident, Ms. Pak-Byeon's body and extremities would have moved rearward relative to the subject vehicle's interior.[4,5,6,7] This rearward motion would have been supported by the seatback. Ms. Pak-Byeon's upper torso would have loaded into the seat structures and if there was rebound, the seat belt would have engaged Ms. Pak-Byeon's bony left clavicle had the accelerations exceeded 0.7g.[8] This interaction with the seat back and seat belt would have limited her motion during the subject incident.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[9,10,11,12] These activities would directly load Ms. Pak-Byeon's shoulders to comparable or greater loads than the subject incident.

The low accelerations in the subject incident and the restraint provided by the seatback, were such that any motion of Ms. Pak-Byeon's shoulders would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported left shoulder and costal region biomechanical failures of Ms. Pak-Byeon cannot be made.

Regarding Ms. Pak-Byeon's activities, she testified that she worked as a nanny 30 to 40 hours per week. This required her to carry, lift, and care for children ages 1 and 3 years old. Additionally, she testified that she enjoyed hiking, running, and occasionally played sports like basketball, soccer, and volleyball. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Pak-Byeon and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

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1 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

2 Melenevsky, Y., Yablon, C.M., Ramappa, A., Hochman, M.G. (2009) "Clavicle and Acromioclavicular Joint Injuries: A Review of Imaging, Treatment, and Complications." Skeletal Radiology. 40:831-842.

3 Simovitch, R., Sanders, B., Ozbaydar, M., Lavery, K., Warner, J.J.P., (2009) "Acromioclavicular Joint Injuries: Diagnosis and Management." J Am Acad Orthop Surg. 4:207-219.

4 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

5 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.

6 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

7 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions*. (No. 2010-01-0067). SAE Technical Paper.

8 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

9 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics*. *42*(12), 1840-1849.

10 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics*, *19*(6), 586-594.

11 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).

12 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics*, *40*(10), 2139-2149.

Conclusions:

Based upon the additional information, my opinions from my report dated January 5, 2016 have not changed.

Additionally, there is no biomechanical failure mechanism present in the subject incident to account for Ms. Pak-Byeon's claimed shoulder biomechanical failures. As such, a causal relationship between the subject incident and the shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Biomechanist

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January 8, 2016

Alan Garrett, Esquire
Law Offices of Sweeney, Heit & Dietzler
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Suite 500
Seattle, WA 98101

Re: *Dupart, Kirsten v. Christopher Aakre*
ARCCA Case No.: 3271-362

Dear Mr. Garrett:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Kirsten Dupart. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on February 18, 2012, Ms. Kirsten Dupart was the seat-belted driver of a 2001 Honda Civic traveling on Avondale Road in Redmond, Washington. Mr. Matt Harris was the front passenger of the subject Honda. Mr. Christopher Aakre was the driver of a 2007 Hyundai Santa Fe traveling immediately behind the subject Honda. While stopped at a yield sign preparing to turn right, contact was made between the front of the incident Hyundai and the rear of the subject Honda. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Nineteen (19) color photographic reproductions of the subject 2001 Honda Civic
- Fifteen (15) color photographic reproductions of the incident 2007 Hyundai Santa Fe
- Safeco Insurance Company of Illinois Estimate of Record for the subject 2001 Honda Civic [March 2, 2012]
- Safeco Insurance Company of Illinois Estimate of Record for the incident 2007 Hyundai Santa Fe [February 27, 2012]
- Deposition Transcript of Kirsten J. Dupart, *Kirsten J. Dupart vs. Christopher Aakre and Jane Doe Aakre* [June 29, 2015]
- Medical Records pertaining to Kirsten Dupart
- VinLink data sheet for the subject 2001 Honda Civic
- Expert AutoStats data sheets for a 2001 Honda Civic
- VinLink data sheet for the incident 2007 Hyundai Santa Fe
- Expert AutoStats data sheets for a 2007 Hyundai Santa Fe
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

ARC A

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Dupart claims were caused by the subject incident on February 18, 2012;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2001 Honda Civic;
3. Determine Ms. Dupart's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Dupart's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Dupart attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
    - C5-6 and C6-7 disc bulging
    - C7-T1 cystic structure
- Thoracic Spine
    - Sprain/strain

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2001 Honda Civic and the incident 2007 Hyundai Santa Fe in association with accepted scientific methodologies. [11,12]

The repair estimate for the subject 2001 Honda Civic reported repairs, not replacement, of the rear bumper cover, which is consistent with the reviewed photographs (Figure 1). The photographs depicted scuffs and paint chips to the rear bumper, predominately on the center and right side. There was no residual crush or malalignment of the rear bumper cover with respect to the tail lights, trunk lid, or quarter panels. There was no indication of any structural component damage. Ms. Dupart testified that she *"noticed some damage, but it was minimal"*.

Figure 1: Reproductions of photographs of the subject 2001 Honda Civic

The repair documents for the incident 2007 Hyundai Santa Fe indicated there was damage to the front bumper cover and lower cover. The repair estimate notes that the front bumper cover was cracked approximately 24 inches from the ground behind the license plate. The photographs depicted scuff marks to the right front corner of the bumper cover, displacement of the left lower cover near the left fog lamp, and the lower portion of the license plate was bent inward (Figure 2).

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 2: Reproductions of photographs of the incident 2007 Hyundai Santa Fe

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Honda Civic, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested a 2001 Honda Civic in a 5 mile-per-hour rear impact into a flat barrier.[14] The test Honda Civic sustained damage to the bumper reinforcement, frame sidemembers, engine mount, and required a rear unibody realignment. The primary damage to the subject Honda Civic was to the rear bumper cover. Thus, because the test Honda Civic in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the Honda Civic speed at or below the test speed of 5 miles-per-hour. Using conservation of momentum with a coefficient of restitution of 0.3, the subject Honda Civic experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of

[13] Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

[14] Insurance Institute for Highway Safety Low-Speed Crash Test Report, 2001 Honda Civic, January 2001.

6.4 miles-per-hour or less.[15,16] Additionally, the above analysis is consistent with an energy crush analysis to the front of the incident Hyundai Santa Fe.[17,18,19,20,21,22]

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.4 mile-per-hour Delta-V is 2.0g.[23,24,25,26] By the laws of physics, the average acceleration experienced by the subject Honda Civic in which Ms. Dupart was seated was significantly less than 2.0g.

The acceleration experienced due to gravity is 1g. This means that Ms. Dupart experiences 1g of loading while in a sedentary state. Therefore, Ms. Dupart experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[27] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Dupart's medical records indicated she was 67 inches in height, weighed between 126 and 136 lbs., and was 26 years old at the time of the subject incident. Ms. Dupart testified that she was fully stopped, unaware, and turned to the right. She further testified that her head hit the headrest, then went forward and made contact with the steering wheel.

The laws of physics dictate that when the subject Honda Civic was contacted in the rear, it would have been pushed forward causing Ms. Dupart's seat to move forward relative to her body. This motion would result in Ms. Dupart moving rearward relative to the interior of the Honda Civic and loading into the seatback structures. Ms. Dupart's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Dupart was wearing the available three point restraint. As Ms. Dupart's body moved rearward, the seat belt would retract with her body.

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15 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

16 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configuratians*. (No. 2001-01-0891). SAE Technical Paper.

17 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 1998 Dodge Dakota, April 1998.

18 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

19 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

20 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

21 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

22 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

23 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

24 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

25 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

26 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

27 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Dupart's body to the seat structures. Based on the low accelerations of the subject incident, there would not have been sufficient forces to cause Ms. Dupart's head to make contact with the steering wheel. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Dupart would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the Honda Civic and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Dupart was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[28,29]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

According to the available documents, Ms. Dupart was diagnosed with a cervical sprain/strain. An MRI report on October 25, 2012, identified minimal annular disc bulging at the C5-6 and C6-7 levels, as well as a cystic structure at C7-T1 adjacent to the left C8 nerve root. On February 19, 2015, Ms. Dupart underwent a hemilaminotomy at the C7 level to remove the C7-T1 synovial cyst.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. The primary mechanism for cervical disc type of biomechanical failure occurs when the head hyperextends over the headrest of the seat. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted

28 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

29 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck.* (No. 710855). SAE Technical Paper.

mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[30] In the absence of this acute biomechanical failure mechanism for cervical disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[31,32] The primary mechanism for a synovial spinal cyst is degeneration of the spine, not acute biomechanical failure.[33]

In a rear impact that produces motion of the Honda Civic, the Honda Civic would be pushed forward and Ms. Dupart would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2001 Honda Civic revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.0 inches in the full down position, and 33.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Dupart revealed she would have a normal seated height of 33.9 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Dupart's cervical spine would have undergone only a subtle degree of the characteristic response phases.[34] Furthermore, Ms. Dupart indicated that her head made contact with the headrest. The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[35] The cervical loads were within physiologic limits and Ms. Dupart would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[36,37,38]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[39,40,41,42,43] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical

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30 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

31 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

32 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

33 Found, E. nnd Bewyer, D. (2011). "Cervical Synovial Cyst: Case Report" *Iowa Orthopaedic Journal* 31:215-218.

34 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

35 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

36 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Iujuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

37 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influeuce of End Condition on Human Cervical Spiue Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

38 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

39 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

40 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

41 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

42 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

43 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[44] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [45,46,47,48] The available documents reported Ms. Dupart was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[49]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Dupart cannot be made.

Thoracic Spine

According to the available documents, Ms. Dupart was diagnosed with a thoracic sprain/strain. On March 9, 2012, an X-ray report of Ms. Dupart's thoracic spine was considered normal.

During an event such as the subject incident, the thoracic spine of Ms. Dupart is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Dupart's thoracic spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

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44 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

45 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

46 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

47 Fuuk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Iujury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

48 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

49 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

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Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[50,51,52,53] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[54] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[55,56] Ms. Dupart's thoracic spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[57,58,59,60,61]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight ,along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[62,63,64,65] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or

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50 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

51 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

52 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

53 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

54 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

55 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupaut Sitting Position on the Kinematics and Kinetics of the Lumbar Spiue During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

56 Gates, D., Bridges, A., Welch, T.D.J., et nl. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

57 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Positiou on the Kiuematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

58 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

59 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

60 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushiug and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

61 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

62 Rohlmann, A., Claes, L.E., Bergmaun, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

63 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmaun, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

64 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

65 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Rolc of the Trunk iu Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

Figure 2: Reproductions of photographs of the incident 2007 Hyundai Santa Fe

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Honda Civic, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested a 2001 Honda Civic in a 5 mile-per-hour rear impact into a flat barrier.[14] The test Honda Civic sustained damage to the bumper reinforcement, frame sidemembers, engine mount, and required a rear unibody realignment. The primary damage to the subject Honda Civic was to the rear bumper cover. Thus, because the test Honda Civic in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the Honda Civic speed at or below the test speed of 5 miles-per-hour. Using conservation of momentum with a coefficient of restitution of 0.3, the subject Honda Civic experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of

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13 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

14 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2001 Honda Civic, January 2001.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[76,77,78,79] Ms. Dupart testified she was capable of performing daily activities. These activities would directly load Ms. Dupart's shoulders to comparable or greater loads than the subject incident.

The low accelerations in the subject incident and the restraint provided by the seatback, were such that any motion of Ms. Dupart's left shoulder would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported left shoulder biomechanical failures of Ms. Dupart cannot be made.

Personal Tolerance Values

According to the available documents, Ms. Dupart was employed at an elementary school at the time of the subject incident. She testified that she was capable of lifting groceries, vacuuming, and weight strengthening. Ms. Dupart's hobbies included playing basketball, snowboarding, running 5-6 miles, hiking, and boating. In her testimony, Ms. Dupart specifically mentioned that she *"was a very avid runner"*. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Dupart and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[80]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Dupart's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Dupart using peer-reviewed and generally-accepted methodologies.

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76 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics, 42*(12), 1840-1849.

77 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics, 19*(6), 586-594.

78 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).

79 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics, 40*(10), 2139-2149.

80 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On February 18, 2012, Ms. Kirsten Dupart was the seat-belted driver of a 2001 Honda Civic that was stopped on Avondale Road in Redmond, Washington, when the subject Honda Civic was contacted in the rear at low speed by a 2007 Hyundai Santa Fe.
2. The severity of the subject incident was below 6.4 miles-per-hour with an average acceleration less than 2.0g.
3. The acceleration experienced by Ms. Dupart was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the Honda Civic during the subject incident would tend to move Ms. Dupart's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Dupart's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Dupart's claimed thoracic biomechanical failures. As such, a causal relationship between the subject incident and the thoracic biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Dupart's claimed left shoulder biomechanical failures. As such, a causal relationship between the subject incident and the left shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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January 26, 2016

Stacy DeMass, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Mekhael, Refaat v. Heather Glynn*
Claim No.: 465382645036
ARCCA Case No.: 3271-356

Dear Ms. DeMass:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Refaat Mekhael. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on November 27, 2013, Mr. Refaat Mekhael was the seat-belted driver of a 1994 Oldsmobile Eighty Eight stopped in the left turn lane on westbound Coal Creek Parkway Southeast in Bellevue, Washington. Ms. Ledia Mekhael was the seat-belted front passenger in the subject Oldsmobile. Ms. Heather Glynn was the driver of a 2006 BMW 325i immediately behind the subject Oldsmobile. According to the State of Washington Police Traffic Collision Report, while the subject Oldsmobile was stopped, contact was made between the front of the incident BMW and the rear of the Oldsmobile. No airbags were deployed and neither vehicle was towed from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. E288912* [November 27, 2013]
- Fifteen (15) color photographic reproductions of the subject 1994 Oldsmobile Eighty Eight
- Twelve (12) color photographic reproductions of the incident 2006 BMW 325i
- Deposition Transcript of Refaat Mekhael, *Ledia Mekhael and Refaat Mekhael vs. Heather Glynn and John/Jane Doe Glynn* [December 11, 2015]
- Deposition Transcript of Ledia Mekhael¸ *Ledia Mekhael and Refaat Mekhael vs. Heather Glynn and John/Jane Doe Glynn* [December 11, 2015]
- Demands Letter for Refaat Mekhael [January 9, 2015]
- Safeco Insurance Company of Illinois Estimate of Record for the subject 1994 Oldsmobile Eighty Eight [December 6, 2013]
- Medical Records pertaining to Refaat Mekhael
- VinLink data sheet for the subject 1994 Oldsmobile Eighty Eight
- Expert AutoStats data sheets for a 1994 Oldsmobile Eighty Eight
- VinLink data sheet for the incident 2006 BMW 325i
- Expert AutoStats data sheets for a 2006 BMW 325i
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

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Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Mr. Mekhael claims were caused by the subject incident on November 27, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1994 Oldsmobile Eighty Eight;
3. Determine Mr. Mekhael's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. Mekhael's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Mr. Mekhael attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair estimates of the subject 1994 Oldsmobile Eighty Eight and photographic reproductions of the incident 2006 BMW 325i in association with accepted scientific methodologies. [11,12]

The Estimate of Repair for the subject 1994 Oldsmobile Eighty Eight reported damage to the left tail lamp assembly. The photographs for the subject 1994 Oldsmobile Eighty Eight showed no residual crush to the rear of the vehicle, however, there was evidence that one of the rear bumper isolators had stroked. There were some scratches to the left corner of the rear bumper below the trim, and a small crack to the lower corner of the left tail light. The trim around the rear bumper cover was sticking out in various places. The rear bumper cover was in proper alignment with the quarter panels, tail lights, and trunk lid. Mr. Mekhael's testimony indicated that the damages to the subject Oldsmobile were minimal, stating, *"wasn't that damages that much"*.




[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

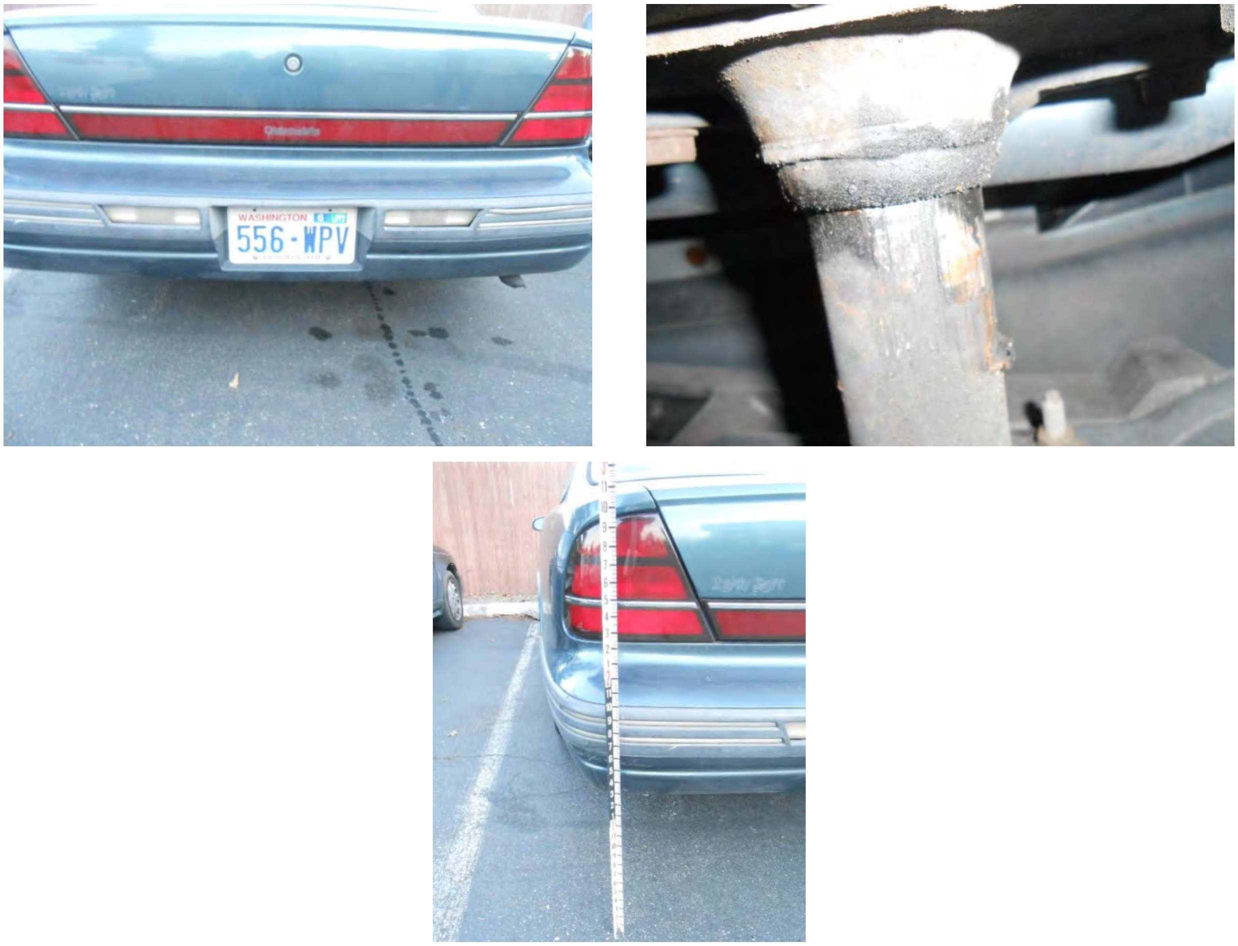

Figure 1: Reproductions of photographs of the subject 1994 Oldsmobile Eighty Eight

The photographs for the incident 2006 BMW 325i depicted no residual crush or signs of structural damage (Figure 2). The front bumper was well aligned with the head lights, grille, hood, and front fenders. There were minor chips and paint scratches to the right side of the front bumper cover.

Figure 2: Reproductions of photographs of the incident 2006 BMW 325i

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident BMW 325i can be used to resolve the loads sustained by the subject Oldsmobile Eighty Eight. That is, the loads sustained by the incident 325i are equal and opposite to those of the subject Eighty Eight. Furthermore, energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17]

Analyses of the photograph and geometric measurements of the incident 2006 BMW 325i revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the front of a BMW 325i of the same production year would result in significant and visibly noticeable crush across the entirety of the incident BMW's front structure, with a residual crush of 2.75 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the

[13] Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.
[14] Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.
[15] Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.
[16] Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.
[17] Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.
[18] EDCRASH, Engineering Dynamics Corp.
[19] PC-Crash Collision Software.

vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20] The lack of significant structural crush to the entire front of the incident BMW along with the conservation of momentum indicates that the subject incident is consistent with a collision resulting in a Delta-V below 8.9 miles per hour for the subject Oldsmobile Eighty Eight. Additionally, the above analysis is consistent with an energy crush analysis to the rear of the subject Oldsmobile Eighty Eight.

Furthermore, the rear bumper of the subject Oldsmobile was equipped with two bumper shock isolators (also called hydraulic energy absorbers). The shock isolator acts as a shock, or impact absorber, between the bumper face bar and the structure of the vehicle. Compression testing of rear-bumper shock isolators was performed on a 1995 Oldsmobile Eighty Eight, essentially the same vehicle as the 1994 Oldsmobile Eighty Eight. The bumper isolator is an energy absorbing device and is designed to compress and allow for displacement of the bumper relative to the vehicle. After the load is removed, the bumper should return to its original position if the limit of the isolator was not exceeded. However, if the isolator is stroked beyond its maximum displacement, any additional force would be applied to deforming the structure of the vehicle. Newton's Second Law, which states that force is equivalent to the product of mass and acceleration, can be used to determine the maximum acceleration of the subject Oldsmobile. Testing indicated that at maximum stroke, for both isolators, the acceleration of the incident vehicle would be a maximum of 1.0g, based upon the published weight of the subject Oldsmobile.[21,22,23,24] By the laws of physics, the peak acceleration experienced by the subject Oldsmobile in which Mr. Mekhael was seated was significantly less than 1.0g.

The acceleration experienced due to gravity is 1g. This means that Mr. Mekhael experiences 1g of loading while in a sedentary state. Therefore, Mr. Mekhael experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[25] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

21 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

22 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

23 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

24 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

25 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Kinematic Analysis:

Mr. Mekhael's medical records indicated he was 66 inches in height, weighed approximately 180 lbs., and was 49 years old at the time of the subject incident. Mr. Mekhael testified that his car was stopped at the time of the subject incident. He further testified that he blacked out after the impact.

The laws of physics dictate that when the subject Oldsmobile Eighty Eight was contacted in the rear, it would have been pushed forward causing Mr. Mekhael's seat to move forward relative to his body. This motion would result in Mr. Mekhael moving rearward relative to the interior of the Oldsmobile Eighty Eight and loading into the seatback structures. Mr. Mekhael's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Mr. Mekhael was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Mr. Mekhael's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Mekhael would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the Oldsmobile Eighty Eight and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Mekhael was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[26,27]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

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[26] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[27] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

Cervical Spine

Mr. Mekhael was diagnosed with a cervical sprain/strain, as well as cervical disc degeneration. An X-ray report of his cervical spine on December 3, 2013, identified lordosis reversal and spondylosis at C5-6 and C6-7 levels, but no acute fracture.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the Oldsmobile Eighty Eight, the Oldsmobile Eighty Eight would be pushed forward and Mr. Mekhael would have moved rearward relative to the vehicle, until his motion was stopped by the seatback and seat bottom. Examination of an exemplar 1994 Oldsmobile Eighty Eight revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 26.0 inches in the full down position, and 29.25 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Mr. Mekhael revealed he would have a normal seated height of 33.4 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Mr. Mekhael's cervical spine would have undergone only a subtle degree of the characteristic response phases.[28] The load would have been applied predominantly horizontal to his cervical spine and minimized relevant cervical loads.[29] The cervical loads were within physiologic limits and Mr. Mekhael would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[30,31,32]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[33,34,35,36,37] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[38] Additional studies at severity

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[28] Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

[29] Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

[30] Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

[31] Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

[32] Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

[33] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[34] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

[35] Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

[36] Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

[37] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[38] Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [39,40,41,42] The available documents reported Mr. Mekhael was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Mekhael cannot be made.

Lumbar Spine

According to the available documents and medical records, Mr. Mekhael complained of back and hip pain, and was diagnosed with a lumbar spine sprain/strain. An MRI of Mr. Mekhael's pelvis on July 18, 2014, stated *"essentially normal study without explanation for the patient's symptoms"*. An X-ray of his lumbar spine on December 3, 2013, reported minimal degenerative spurring at L3-4 and L4-5 levels with no disc space narrowing.

During an event such as the subject incident, the lumbar spine of Mr. Mekhael is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Mr. Mekhael's lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the lumbar spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur. Similarly, the pelvis (hip) would also be well constrained and not experience the biomechanical failure mechanism.

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[39] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

[40] Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

[41] Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

[42] Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

[43] Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[44,45,46,47] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[48] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[49,50] Mr. Mekhael's lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[51,52,53,54,55]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [56,57,58,59] Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to

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44 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

45 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

46 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

47 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

48 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

49 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

50 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

51 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

52 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

53 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

54 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

55 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

56 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

57 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

58 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

59 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

or greater than the subject incident.[60,61] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[62] According to the available documents, Mr. Mekhael was capable of performing daily activities. A segmental analysis of Mr. Mekhael demonstrated that as he lifted objects during daily tasks, the forces applied to his lower spine would have been comparable to or greater than those during the subject incident.[63,64,65]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Mekhael, a causal link between the subject incident and claimed thoracic biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Mr. Mekhael was employed as a gas station cashier. He stated that one of his hobbies was playing soccer with his children. The available documents indicated that Mr. Mekhael was capable of performing normal activities of daily living without biomechanical failure. These common activities can produce greater movement, or stretch, to the soft tissues of Mr. Mekhael and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[66]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Mekhael's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding

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60 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

61 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

62 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

63 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

64 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

65 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

66 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

of the unique personal tolerance level of Mr. Mekhael using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 27, 2013, Mr. Refaat Mekhael was the seat-belted driver of a 1994 Oldsmobile Eighty Eight that was stopped on Coal Creek Parkway Southeast in Bellevue, Washington, when low speed contact occurred between the rear of the subject Oldsmobile Eighty Eight and the front of a 2006 BMW 325i.
2. The severity of the subject incident had a peak acceleration less than 1.0g.
3. The acceleration experienced by Mr. Mekhael was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the Oldsmobile Eighty Eight during the subject incident would tend to move Mr. Mekhael's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Mekhael's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Mekhael's claimed lumbar biomechanical failures. As such, a causal relationship between the subject incident and the lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

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Re: *Ung, Chhung Hang and Keang Ly Taing v. Abdulkadir Mohamed and Sagal Aden*
Claim No.: 300733645007
ARCCA Case No.: 3271-373

Dear Mr. Lovejoy:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Chhung Ung and Keang Taing. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the testimony and other available documents, on November 29, 2013, Mr. Chhung Ung was the seat-belted driver of a 2013 Toyota Camry traveling eastbound on South Holly Park Drive in Seattle, Washington. Ms. Keang Taing was the seat-belted front passenger. Ms. Linda and Kimberly Taing were passengers in the left and right rear seats, respectively. Mr. Abdulkadir Mohamed was the driver of a 1997 Nissan Altima parked on the eastbound curb on South Holly Park Drive. Mr. Yesia Abdi was the right rear passenger in child seat.

The sequence of events leading to the subject incident is in dispute. According to Mr. Ung and Ms. Taing, as the subject Camry approached the incident Altima, the Altima began merging into traffic and made contact with the subject Camry. According to Mr. Mohamed, as the subject Camry was passing the incident Altima, the subject Camry swerved into the Nissan. In either scenario, contact was made between the right side of the subject Camry and the left front side of the incident Altima. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. 3643180* [November 29, 2013]
- One (1) color photographic reproduction of the subject 2013 Toyota Camry
- Seven (7) black and white photographic reproductions of the subject 2013 Toyota Camry
- Fifteen (15) color photographic reproductions of the incident 1997 Nissan Altima and subject incident scene
- Burien Toyota-Chevrolet Supplement of Record 1 with Summary for the subject 2013 Toyota Camry [January 30, 2014]
- Deposition Transcript of Keang L. Taing, *Chhung Hang Ung and Keang Ly Taing vs. Abdulkadir A. Mohamed and Sagal A. Aden* [May 28, 2015]
- Medical Records pertaining to Chhung Ung
- Medical Records pertaining to Keang Taing
- VinLink data sheet for the subject 2013 Toyota Camry
- Expert AutoStats data sheets for a 2013 Toyota Camry
- VinLink data sheet for the incident 1997 Nissan Altima
- Expert AutoStats data sheets for a 1997 Nissan Altima
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Mr. Ung and Ms. Taing claim were caused by the subject incident on November 29, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Ung and Ms. Taing were occupying;
3. Determine Mr. Ung and Ms. Taing's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident.
5. Evaluate Mr. Ung and Ms. Taing's personal tolerances in the context of their pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and their reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Mr. Ung attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic and Lumbar Spine
    - Sprain/strain

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

According to the available documents, Ms. Taing attributes the following biomechanical failures as a result of the subject incident:

- Right Shoulder
  - Sprain/strain
- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

<u>Damage and Incident Severity:</u>

The severity of the incident was analyzed by using the photographic reproductions and repair documents of the subject 2013 Toyota Camry and photographic reproductions of the incident 1997 Nissan Altima in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject Toyota Camry reported damage to the right fender, right door shell, upper hinge of the front right door, right quarter panel, and right hinge pillar, which is consistent with the photographs (Figure 1). The reviewed photographs of the subject Toyota depicted horizontal scrapes from the rear portion of the right front fender to just rear of the front right door shell. The rear portion of the right fender was crushed, as well as the front portion of the right front door shell just behind the leading edge of the door.

[11] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

[12] Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

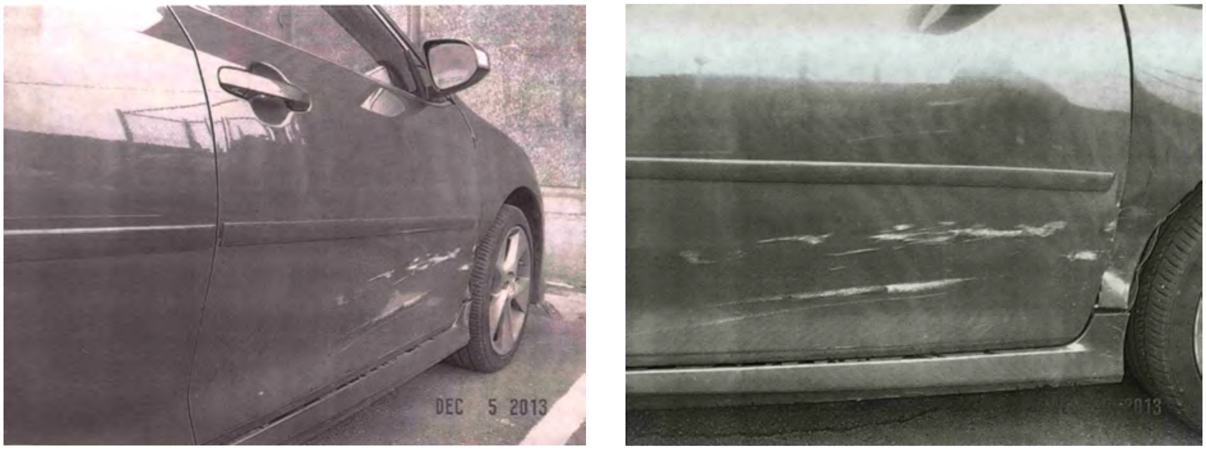

Figure 1: Reproductions of photographs of the subject 2013 Toyota Camry

The photographic reproductions for the incident Nissan Altima depicted damage to the front left fender (Figure 2). The front left fender was crushed just above the reflector to the height of the headlight. There were paint chips, scratches, and discolorations throughout the rear of the Nissan, including a horizontal scrape to the left rear bumper cover. However, the State of Washington Police Traffic Collision Report and other available documents indicate that only the front crush was related to the subject incident.

Figure 2: Reproductions of photographs of the incident 1997 Nissan Altima

Scientific analyses of the photographs and geometric measurements of the vehicles along with the available testimony, identified that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces. As such, the subject incident was consistent with a sideswipe event.[13] Further, Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Nissan Altima can be used to resolve the loads sustained by the subject Toyota Camry. That is, the loads sustained by the incident Altima are equal and opposite to those of the subject Camry. The laws of physics dictate that the lateral force exerted to the front bumper of the incident Altima was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the incident Altima as a result of the sideswipe event was significantly less than 1.0g.[14] Using an acceleration pulse with the shape of a haversine and duration of 200 milliseconds,[15] the Delta-V associated with the subject incident is less than 2.2 mph. Accounting for the larger mass of the subject Camry, which includes the vehicle weight and the additional weight of the occupants, the peak acceleration to the subject Toyota Camry would also be significantly less than 1.0g. The lateral forces to the Toyota Camry associated with the subject incident were calculated to be less than 0.7g.

Comparatively, hard braking generates an acceleration of approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that Mr. Ung and Ms. Taing experience 1g of loading while in a sedentary state. Therefore, Mr. Ung and Ms. Taing experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[16] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

In her deposition, Ms. Taing testified that the subject Toyota Camry was traveling 20-25 mph, and she was unaware of the oncoming impact. She further stated that *"it was a strong impact, and then my body was moved backward because my husband put on the brake"*. Ms. Taing testified that her right shoulder and right leg struck the door. The available documents indicated that Mr. Ung and Ms. Taing were wearing the available three-point restraint.

The laws of physics dictate that had there been enough energy transferred to initiate motion, the sideswipe event would have caused the subject Toyota to decelerate longitudinally and accelerate slightly leftward. Scientific literature indicates that provided the low accelerations of the event,

13 Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

14 Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions, (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

15 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

16 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

little occupant motion would have occurred.[17,18] ARCCA, Incorporated has conducted experiments that exposed motor vehicles to low severity contact events similar to the subject incident. These experiments included tracking the movement of human volunteers and anthropomorphic test devices (ATDs) during the testing. Results demonstrated that neither the human volunteers nor the ATDs experienced any significant motion relative to the vehicle's interior. If occupant motion were assumed to have occurred during the subject incident, the laws of physics and results from previous studies[19,20] dictate that Mr. Ung and Ms. Taing would have tended to move forward and rightward relative to the vehicle's interior. This motion would have been controlled and supported by the friction generated at their seat bottom and the three point restraint. Specifically, the three-point restraint would have locked during the subject incident had the acceleration exceeded 0.7g and limited their forward body excursion.[21] Provided the low accelerations of the subject incident, and the supports described, the bodily response of Mr. Ung and Ms. Taing would have been limited to well within normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Ung and Ms. Taing was well within the limits of human tolerance and well below the acceleration levels that they likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link their reported biomechanical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

Mr. Ung and Ms. Taing were diagnosed with sprain/strain biomechanical failures. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its

17 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

18 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

19 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

20 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

21 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

22 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

23 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Right Shoulder

According to the medical records, Ms. Taing attributes a right shoulder sprain/strain to the subject incident. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[24,25,26] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[15]

As stated previously, during the subject incident the Toyota Camry would have decelerated longitudinally and accelerated leftward, and Ms. Taing would have moved forward and to the right relative to the interior of the vehicle. Given the low accelerations of the event, the motion of Ms. Taing would have been well supported by the three point restraint and seat bottom cushion. Ms. Taing testified that her right shoulder made contact with the front right door. The three-point restraint she was wearing would have engaged Ms. Taing's bony right clavicle had the accelerations exceeded 0.7g. [27] This interaction would have limited her motion and contact forces with the door during the subject incident.

Several cadaveric studies have directly loaded the shoulder under greater lateral impact forces than the subject incident without biomechanical failure to the glenohumeral joint, including labral tears.[28,29,30] Fugger et al. performed multiple lateral vehicle impacts to both males and females and found that only transient pain lasting less than two weeks was reported.[31]

24 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.
25 Melenevsky, Y., Yablon, C.M., Ramappa, A., Hochman, M.G. (2009) "Clavicle and Acromioclavicular Joint Injuries: A Review of Imaging, Treatment, and Complications." Skeletal Radiology. 40:831-842.
26 Simovitch, R., Sanders, B., Ozbaydar, M., Lavery, K., Warner, J.J.P., (2009) "Acromioclavicular Joint Injuries: Diagnosis and Management." J Am Acad Orthop Surg. 4:207-219.
27 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.
28 Bolte, J.H. et al. (2000). Shoulder Response Characteristics and Injury Due to Lateral Glenohumeral Joint Impacts (SAE 20000-01-SC18). Warrendale, PA. Society of Automotive Engineers.
29 Irwin, A.L. et al. (1993). Displacement Responses of the Shoulder and Thorax in Lateral Sled Impacts (SAE 933124). Warrendale, PA. Society of Automotive Engineers.
30 Koh, S.W., Cavanaugh, J.M., Zhu, J. (2001) Injury and Reposne of the Shoulder in Lateral Sled Tests (SAE 2001-22-0005). Warrendale, PA. Society of Automotive Engineers.
31 Fugger Jr., T.F., et al. (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

The available documents indicated that Ms. Taing performed normal activities prior to the subject incident without biomechanical failure. These activities would directly load Ms. Taing's shoulders multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[32,33,34,35] These data demonstrate that the shoulder forces and accelerations of the subject incident did not exceed Ms. Taing's personal tolerance.

As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported right shoulder biomechanical failures of Ms. Taing cannot be made.

Cervical Spine

According to the medical records, Mr. Ung and Ms. Taing attributed a cervical sprain/strain to the subject incident. As described previously, the sideswipe event would have caused the subject Toyota Camry to deceleration longitudinally and accelerate leftward. Scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, little occupant motion would have occurred.[36,37] If occupant motion were assumed, Mr. Ung and Ms. Taing would have moved forward and rightward relative to the vehicle's interior.[38,39] This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Toyota. Mr. Ung and Ms. Taing's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[40] As a result, Mr. Ung and Ms. Taing's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[41]

Many research studies support these above conclusions. Human volunteers have been exposed to frontal and lateral impact accelerations at levels comparable to, and greater than that of the subject incident.[42,43,44,45,46,47,48,49,50,51,52] Participants moved toward the point of impact while their

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32 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

33 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

34 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

35 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

36 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

37 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

38 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

39 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

40 Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

41 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

42 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

response was controlled by the three-point restraint, seat structures, and vehicle interior components. None of the volunteers reported cervical trauma in response to this testing. Further research has exposed cadavers to impact accelerations within the biomechanical failure range.[53,54] These results demonstrated that the accelerations during the subject incident were maintained well within human tolerance as none of the cadaveric testing resulted in cervical trauma at acceleration levels consistent with the subject incident. The accelerations during the subject incident were maintained within published guidelines for safe human exposure to frontal and lateral impact accelerations.[55] In addition, these studies demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[56,57] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Research by Funk et al.[58] demonstrated that a simple head shake or a self-inflicted hand strike to the head induces accelerations comparable to or greater than the subject incident. The available documents indicated that Mr. Ung and Ms. Taing performed daily activities without biomechanical failure prior to the subject incident. These activities would have generated cervical forces that were

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43 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

44 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

45 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

46 Matsushita, T., Sato, T.B., Hirabayashi, K., et al. (1994). X-ray Study of the Human Neck Motion Due to Head Inertia Loading (SAE 942208). Warrendale, PA. Society of Automotive Engineers.

47 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

48 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

49 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

50 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

51 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

52 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

53 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

54 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

55 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

56 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

57 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

58 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

comparable to and greater than those of the subject incident.[59,60,61,62] These data demonstrate that the cervical forces of the subject incident did not exceed Mr. Ung and Ms. Taing's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Ung and Ms. Taing cannot be made.

Thoracic and Lumbar Spine

In this type of collision, the motion of Mr. Ung and Ms. Taing's thoracic and lumbar regions would have been well supported and constrained. Again, scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, little occupant motion would have occurred.[63,64] Provided sufficient energy to overcome Mr. Ung and Ms. Taing's muscle reaction forces, their bodies would have moved forward and rightward relative to the Toyota's interior. As described previously, Mr. Ung and Ms. Taing indicated they were wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited their forward body excursion.[65] The seat belt would have primarily engaged Mr. Ung and Ms. Taing's pelvises and bony left and right clavicles, respectively, distributing the load over their entire torsos and limiting their motion. Therefore, Mr. Ung and Ms. Taing's thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Mr. Ung and Ms. Taing's thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

Researchers have frequently exposed human volunteers to both frontal and lateral impact accelerations at levels comparable to and greater than that of the subject incident.[66,67,68,69,70,71,72,73] No thoracic or lumbar biomechanical failures were reported and

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59 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities." Biomedical Sciences Instrumentation 42: 25-30.

60 Vijayakumar, V., Scher, I., Gloeckner, D.C., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA. Society of Automotive Engineers.

61 Choi, H., and Vanderby, R. (2000). "Muscle Forces and Spinal Loads at C4/5 Level During Isometric Voluntary Efforts." Medicine & Science in Sports & Exercise 830-838.

62 Moroney, S.P., Schultz, A.B., and Miller, J.A.A. (1988). "Analysis and Measurement of Neck Loads." Journal of Orthopaedic Research 6: 713-720.

63 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

64 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

65 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

66 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

67 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

68 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

kinematics documented. Additionally, occupant kinematics were inconsistent with the biomechanical failure mechanism responsible for the thoracic and lumbar failures. Published guidelines for safe human exposure to frontal and lateral impacts are consistent with the results from these studies.[74] These data provide support for the conclusions described previously regarding Mr. Ung and Ms. Taing's response to the subject incident. In addition, these data demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

The subject incident had a peak acceleration significantly below 1.0g. Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[75] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[76] Mr. Ung and Ms. Taing indicated they were capable of performing normal activities of daily living. Studies by Rohlmann et al.[77,78,79] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Ung and Ms. Taing, a causal link between the subject incident and claimed thoracic and lumbar lumbosacral biomechanical failures cannot be made.

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[69] Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

[70] Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

[71] Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

[72] Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

[73] Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

[74] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[75] Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

[76] Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

[77] Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

[78] Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

[79] Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

Personal Tolerance Values

The available documents indicate that Ms. Taing was capable of performing activities of daily living. Ms. Taing testified that she was capable of cleaning her home and grocery shopping, which includes carrying bags of groceries. Daily activities can produce greater movement, or stretch, to the soft tissues of Mr. Ung and Ms. Taing and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[80]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Ung and Ms. Taing's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Ung and Ms. Taing using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 29, 2013, Mr. Chhung Ung and Ms. Keang Taing were the seat-belted driver and front passenger, respectively, of a 2013 Toyota Camry that was contacted in the passenger's side by a 1997 Nissan Altima resulting in a sideswipe collision.
2. The severity of the subject incident was consistent with a peak acceleration significantly less than 1.0g for the subject 2013 Toyota Camry in which Mr. Ung and Ms. Taing were seated.
3. The acceleration experienced by Mr. Ung and Ms. Taing was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. Had the forces of the subject incident been sufficient to overcome the muscle reaction forces, Mr. Ung and Ms. Taing's bodies would have moved forward and rightward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Taing's claimed right shoulder biomechanical failures. As such, a causal relationship between the subject incident and the right shoulder biomechanical failures cannot be made.

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[80] Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Ung and Ms. Taing's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Ung and Ms. Taing's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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March 8, 2016

[redacted]

[redacted]

Dear [redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of [redacted] This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from

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1. Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.
2. Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.
3. Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.
4. King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.
5. King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

The available documents reported on October 10, 2014, [redacted] was the driver of a 2015 Subaru Legacy traveling southbound on SR 167 near milepost 13.95 in Washington. [redacted] was the driver of a 2008 Chevrolet Colorado traveling directly behind the Subaru. The available documents indicated that as the Subaru stopped for traffic, contact occurred between the front of the Chevrolet and the rear of the Subaru.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report, No. E364739
- Six (6) color photographic reproductions of the subject 2015 Subaru Legacy
- Barrett's Collision Center, Inc. Estimate of Record for the subject 2015 Subaru Legacy, October 13, 2014
- Barrett's Collision Center, Inc. Supplement of Record 1 with Summary for the subject 2015 Subaru Legacy, November 12, 2014
- Complaint [redacted] April 27, 2015
- Defendant [redacted] First Set of Interrogatories and Requests for Production of Documents Propounded to Plaintiff, [redacted] September 11, 2015
- Defendant [redacted] Answers and Objections to Plaintiff [redacted] Interrogatories and Requests for Production, [redacted] *and* [redacted] September 23, 2015
- Medical Records pertaining to [redacted]
- VinLink data sheet for the subject 2015 Subaru Legacy
- Expert AutoStats data sheets for a 2015 Subaru Legacy
- VinLink data sheet for the incident 2008 Chevrolet Colorado
- Expert AutoStats data sheets for a 2008 Chevrolet Colorado
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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[6] Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

[7] Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

1. Identify the biomechanical failures that [redacted] claims were caused by the subject incident on October 10, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2015 Subaru Legacy;
3. Determine [redacted] kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate [redacted] personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The medical records indicate [redacted] attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain
  - Aggravation of pre-existing intervertebral disc conditions
- Right Shoulder
  - Sprain/strain, specifically noting the rotator cuff

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions and repair estimates of the subject 2015 Subaru Legacy in association with accepted scientific methodologies. [11,12]

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8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

The repair documents for the subject Subaru reported damage primarily to the rear bumper cover, reinforcement, and the dealer accessory clear mylar due to the subject incident. The reviewed photographs of the subject Subaru were consistent with the repair estimate; the photographs depicted damage primarily to the rear bumper cover (Figure 1).The rear bumper cover damage included a few gouge marks above the left exhaust pipe and a puncture through the bumper cover. Overall, the photographs did not depict significant crush or misalignment of components to the rear of the Subaru.

Figure 1: Reproductions of photographs of the subject 2015 Subaru Legacy

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 2015 Subaru Legacy revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the rear of a 2015 Subaru Legacy would result in significant and visibly noticeable crush across the entire rear of the subject Subaru's rear

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 PC-Crash Collision Software.

structure, with a residual crush of 5.5 inches. This depth of crush would result in damage to the rear bumper structure, pushing it forward into the rear body panel and to the trunk. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V impact than that of the subject incident (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).[20] The lack of significant structural crush to the entire rear of the subject Subaru indicates a collision resulting in a Delta-V significantly below 10 miles per hour.

Furthermore, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject 2015 Subaru Legacy, defined by the photographic reproductions, and confirmed by the repair documents, was used to perform a damage threshold speed change analysis. [21,22] A similar model year Subaru Legacy was tested in a 6.2 mile-per-hour rear full overlap impact into a bumper barrier. [23] The test Subaru Legacy sustained damage to the rear bumper, rear energy absorber, and rear bumper cover. The primary damage to the subject Subaru Legacy was to the rear bumper cover, reinforcement, and the dealer accessory clear mylar. Thus, because the test Civic in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed less than with 6.2 miles-per-hour. Accounting for the coefficient of restitution, the subject incident resulted in a Delta-V consistent with 8.0 miles-per-hour for the subject Subaru Legacy.

Review of the vehicle damage, incident data, published literature, scientific analyses and my experience indicates an incident resulting in a Delta-V consistent with 8.0 miles-per-hour for the subject Subaru Legacy. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 8.0 mile-per-hour impact is 2.4g.[24,25,26,27] By the laws of physics, the average acceleration experienced by the subject Subaru Legacy in which [redacted] was seated was less than 2.4g. This is contrary to what plaintiff noted in the interrogatories where it was stated *she was rear-ended at a high rate of speed.*

The acceleration experienced due to gravity is 1g, which means that [redacted] experiences 1g of loading while in a sedentary state. Therefore, [redacted] experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly

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20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

21 Siegmund, G.P., et al., (1996). U*sing Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*. (No. 960887). SAE Technical Paper.

22 Happer, A.J., Hughes, M.C., Peck, M.D., et al. (2003) *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

23 Insurance Institute for Highway Safety Bumper Evaluation Crash Test Report. 20120 Subaru Legacy, November 2009.

24 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

25 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

26 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

27 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[28] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

<u>Kinematic Analysis:</u>

According to the available medical records [redacted] was 67 inches in height, weighed approximately 213 lbs. and was 32 years of age at the time of the subject incident. The laws of physics dictate that when contact occurred to the rear of the subject Subaru Legacy, the vehicle would have been pushed forward causing [redacted] seat to move forward relative to her body. This rearward motion would result in [redacted] moving rearward relative to the interior of the subject vehicle and her body, specifically her entire torso and pelvis, would load into the seatback structures. The State of Washington Police Traffic Collision Report indicated [redacted] was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system. The restraint provided by the seatback and seat belt system were such that any motion of [redacted] would have been limited to well within the range of normal physiological limits.

<u>Evaluation of Biomechanical Failure Mechanisms:</u>

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to [redacted] was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[29,30]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

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28 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.
29 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
30 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

Cervical Spine

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident.

The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat. In a rear impact that produces motion of the subject vehicle, the Subaru Legacy would be pushed forward and [redacted] would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. The National Highway Traffic Safety Administration (NHTSA) impact safety tests for continued performance and safety monitoring of the automotive industry. Tests for a 2015 Subaru Legacy showed the seated height of a 50th percentile male in the driver's seat was well protected and supported by the head restraint (Figure 2).[31]

Figure 2: 50th Percentile Male Anthropomorphic Test Device in a 2015 Subaru Legacy

Performing an anthropometric regression of [redacted] revealed she would have a normal seated height of 34.1 inches, over half an inch shorter than a 50th percentile male. Of note, in the above photographs the head restraint is in the full up position however, even in the full down position as noted in [redacted] medical records, her head and cervical spine would be well supported. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that [redacted] cervical spine would have undergone only a subtle degree of the characteristic response phases.[32] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[33] The cervical loads were within physiologic limits and [redacted] would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[34,35,36]

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31 National Highway Traffic Safety Administration (2014). New Car Assessment Program Side Barrier Impact Test, Reference No. BT14090212. 2015 Subaru Legacy.

32 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

33 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

34 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[37,38,39,40,41] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[42] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

[redacted] records indicated that she was capable of performing normal daily activities along with strenuous recreational activities. The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [43,44,45,46] Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[47]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a

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35 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

36 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

37 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

38 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

39 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

40 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

41 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

42 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

43 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

44 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

45 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

46 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

47 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

causal link between the subject incident and the reported cervical spine biomechanical failures of [redacted] cannot be made.

Thoracic and Lumbar Spine

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[48,49,50]

During an event such as the subject incident, the thoracic and lumbar spine of [redacted] is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of [redacted] thoracic and lumbar spine. The seatback would limit her range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur. In the absence of this acute biomechanical failure mechanism for lumbar disc failure, scientific investigations have shown that the above lumbar disc diagnoses can be the result of the normal aging process.[51,52]

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[53,54,55,56] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[57] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely

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48 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.
49 Adams, M.A. and Hutton, W.C. (1983) "The Mechanical Function of the Lumbar Apophyseal Joints". SPINE. Vol. 8(3).
50 Gates, D., Bridges, A., Welch, T., et al., (2010). Lumbar Loads in Low to Moderate Speed Rear Impacts (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.
51 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.
52 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.
53 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.
54 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.
55 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.
56 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.
57 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[58,59] [redacted] thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[60,61,62,63,64]

[redacted] records indicated that she was capable of performing normal daily activities along with strenuous recreational activities. Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable or greater than those resulting from subject incident. [65,66,67,68] Further studies of lumbar accelerations during activities of daily living and found accelerations for activities such as sitting, walking, and jumping off a step to be comparable or greater than the subject incident.[69,70] ARCCA has investigated the compressive lumbar force in a 50th Percentile Hybrid III when plopped into a chair, which is consistent with the previous studies. When dropped from a height of approximately 3 and 10 inches, the compressive force on the lumbar spine equated to an acceleration of approximately 1.6g to 4.7g, respectively. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[71] A segmental analysis of [redacted] demonstrated that as she lifted objects during daily tasks, the forces applied to her lumbar spine would have been comparable to or greater than those during the subject incident.[72,73,74]

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58 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

59 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

60 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

61 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

62 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

63 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

64 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

65 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

66 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

67 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

68 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

69 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

70 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

71 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

72 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of [redacted] a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Right Shoulder

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[75,76,77] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

The available documents indicated [redacted] was holding the steering wheel with her right hand. During the subject incident, [redacted] body and extremities would have moved rearward relative to the subject vehicle's interior.[78,79,80,81] This rearward motion would have been supported by the seatback. [redacted] upper torso would have loaded into the seat structures and if there was rebound, the seat belt would have engaged [redacted] bony left clavicle had the accelerations exceeded 0.7g.[82] This interaction with the seat back and seat belt would have limited her motion during the subject incident.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[83,84,85,86] The available documents indicated [redacted] was

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73 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

74 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

75 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

76 Melenevsky, Y., Yablon, C.M., Ramappa, A., Hochman, M.G. (2009) "Clavicle and Acromioclavicular Joint Injuries: A Review of Imaging, Treatment, and Complications." Skeletal Radiology. 40:831-842.

77 Simovitch, R., Sanders, B., Ozbaydar, M., Lavery, K., Warner, J.J.P., (2009) "Acromioclavicular Joint Injuries: Diagnosis and Management." J Am Acad Orthop Surg. 4:207-219.

78 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

79 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.

80 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

81 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions*. (No. 2010-01-0067). SAE Technical Paper.

82 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

83 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics*. *42*(12), 1840-1849.

84 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics*, *19*(6), 586-594.

capable of performing daily activities and strenuous recreational activities without biomechanical failure. These activities would directly load [redacted] right shoulder to comparable or greater loads than the subject incident.

The low accelerations in the subject incident and the restraint provided by the seatback, were such that any motion of [redacted] right shoulder would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported right shoulder biomechanical failures of [redacted] cannot be made.

Personal Tolerance Values

According to the available documents, [redacted] worked full-time approximately 50 hours per work and this required her to travel regularly. Additionally, the documents indicated she participated in recreational activities such as snowboarding, wakeboarding and attending sporting events. These activities can produce greater movement, or stretch, to the soft tissues of [redacted] and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[87]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between [redacted] reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of [redacted] using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On October 10, 2014, [redacted] was the driver of a 2015 Subaru Legacy stopped for traffic on SR 167 in Washington when contact occurred at low speed between the rear of the subject Subaru and the front of a 2008 Chevrolet Colorado.

2. The severity of the subject incident was consistent with 8.0 miles-per-hour with an average acceleration less than 2.4g.

3. The acceleration experienced by [redacted] was within the limits of human tolerance and comparable to that experienced during various daily activities.

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85 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).

86 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics*, *40*(10), 2139-2149.

87 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper.

4. The forces applied to the subject vehicle during the subject incident would tend to move [redacted]s body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed right shoulder biomechanical failures. As such, a causal relationship between the subject incident and the right shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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EXHIBIT
PENGAD 800-631-6989
Probst 39
5-23-17 ArK

March 10, 2016

William Weber, Esquire
Cole, Wathen, Leid & Hall, PC
303 Battery Street
Seattle, WA 98121

Re: *Dworsky, Tina v. American Family*
Claim No.: 00-185-021251
ARCCA Case No.: 4907-001

Dear Mr. Weber:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Tina Dworsky. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

ARCCA INCORPORATED

Incident Description:

According to the available documents, on February 28, 2013, Ms. Tina Dworsky was the seat-belted driver of a 2007 Mercedes Benz ML320 traveling on southbound Interstate 5 near Fife, Washington. Ms. Betty Crum was the driver of a 2006 Ford Freestar traveling immediately behind the subject Mercedes Benz. Ms. Katherine Rabey was the front seat passenger of the incident Ford Freestar. As the subject Mercedes Benz was stopped in traffic, the front of the incident Ford made contact with the rear of the subject Mercedes Benz. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Sixteen (16) color photographic reproductions of the subject 2007 Mercedes Benz ML320
- Rainier Collision Inc. Preliminary Estimate for repairs of the subject 2007 Mercedes Benz ML320 [March 1, 2013]
- Rainier Collision Inc. Estimate of Record for the subject 2007 Mercedes Benz ML320 [March 4, 2013]
- GEICO Estimate of Record for the incident 2006 Ford Freestar [March 6, 2013]
- GEICO Supplement of Record 1 with Summary for the incident 2006 Ford Freestar [March 28, 2013]
- Pattern Interrogatories Defendant to Plaintiff and Answers Thereto, *Tina Dworsky vs. Betty Crum and "John Doe" Crum* [March, 31, 2015]
- Deposition Transcript of Tina Dworsky, *Tina Dworsky vs. Betty Crum and "John Doe" Crum* [August 25, 2015]
- Deposition Transcript of Betty Crum, *Tina Dworsky vs. Betty Crum and "John Doe" Crum* [May 18, 2015]
- Medical Records pertaining to Tina Dworsky
- VinLink data sheet for the subject 2007 Mercedes Benz ML320
- Expert AutoStats data sheets for a 2007 Mercedes Benz ML350
- VinLink data sheet for the incident 2006 Ford Freestar
- Expert AutoStats data sheets for a 2006 Ford Freestar
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

ARCCA INCORPORATED

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Dworsky claims were caused by the subject incident on February 28, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2007 Mercedes Benz ML320;
3. Determine Ms. Dworsky's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Dworsky's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Dworsky attributes the following biomechanical failures as a result of the subject incident:

- Left Shoulder
  - Acromioclavicular joint arthropathy
  - Partial thickness rotator cuff tearing
  - Impingement syndrome
  - Labral tearing
- Cervical Spine
  - Sprain/strain

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

- Thoracic Spine
    - Sprain/strain
- Lumbar Spine
    - Sprain/strain
    - L3-4 mild disc bulge
    - L4-5 mild disc bulge and annular fissure

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2007 Mercedes Benz ML320 and repair estimates of the incident 2006 Ford Freestar in association with accepted scientific methodologies. [11,12]

The Estimate of Record for the subject 2007 Mercedes Benz ML320 reported damage to the rear bumper lower cover, molding, lower shield, right muffler and tailpipe, and rear bumper cover, which is consistent with the reviewed photographs (Figure 1). In addition, the repair documents noted prior damage to the front bumper and hood. There was minor displacement of the lower rear bumper, as well as scratches and minor displacement of the right tailpipe. Scratches were also visible on the right side of the rear bumper cover. Ms. Dworsky testified that the subject Mercedes Benz *"was dented and the back panel was pushed in"*. Ms. Crum testified that the subject Mercedes Benz had *"no damage"*.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

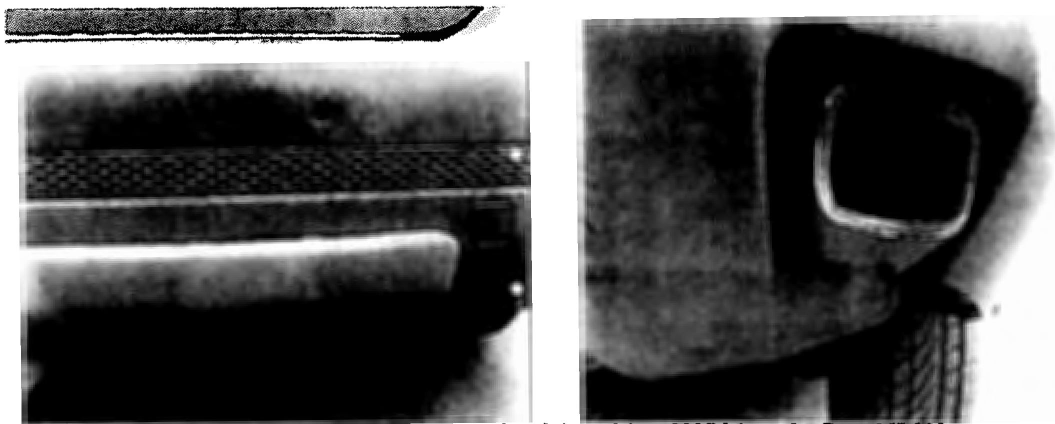

Figure 1: Reproductions of photographs of the subject 2007 Mercedes Benz ML320

The Estimate of Record for the incident 2006 Ford Freestar indicated there was damage primarily to the front bumper cover and mount panel, left headlamp assembly, fog lamp bulbs, and left fender. The repair documents also noted prior damage to the wheels. Ms. Dworsky's testimony described the incident Ford's damage as *"her headlight was broken and she had damage to the front passenger's side…it was pushed in"*. Ms. Crum testified that the incident Ford's *"headlight was kind of pulled out"*. The damages to the incident Ford are consistent with an angled frontal impact, which is consistent with Ms. Crum's testimony that she was merging into the right lane at the time of the incident. The damages to the subject Mercedes Benz also support this, as they are more to the right of the rear bumper.

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Ford Freestar can be used to resolve the loads sustained by the subject Mercedes Benz ML320. That is, the loads sustained by the incident Ford are equal and opposite to those of the subject Mercedes Benz. Furthermore, damage threshold speed change analyses along with the conservation of linear momentum have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16]

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Ford Freestar, defined by the repair estimate, was used to perform a damage threshold speed change analysis.[17] The IIHS tested a 2004 Ford Freestar, production model years 2004-2007, in a 5 mile-per-hour frontal impact into a flat and angled barrier.[18] In the frontal flat impact test, the Ford Freestar sustained damage to the front absorber and bumper reinforcement. In the frontal angled impact test, the Ford Freestar sustained damage to the front bumper cover, absorber, reinforcement, right front frame sidemember end, right front fender, and required a right front unibody pull. The primary

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[13] Siegmund, G.P., et al., (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions.* (No. 960887). SAE Technical Paper.

[14] Meriam, J.L., (1952). Mechanics Part II: Dynamics. John Wiley & Sons, New York.

[15] Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995). *Data and Methods for Estimating the Severity of Minor Impacts.* (No. 950352). SAE Technical Paper.

[16] Happer, A.J., Hughes, M.C., Peck, M.D., et al. (2003) *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems.* (No. 2003-01-0492). SAE Technical Paper.

[17] Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions. (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

[18] Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2004 Ford Freestar. December 2003.

damage to the subject incident Ford Freestar was to the front bumper cover, left headlamp assembly, and left fender. As mentioned previously, the damages to both vehicles, and supported by testimony, is most consistent with an angled frontal impact to the incident Ford. Thus, because the test Ford Freestar in the IIHS frontal impact test sustained significantly greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident. Using the Conservation of Momentum and accounting for restitution, the subject Mercedes Benz ML320 experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of 6.4 miles-per-hour or less.[19,20] Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.4 mile-per-hour Delta-V is 1.9g.[21,22,23,24] By the laws of physics, the average acceleration experienced by the subject Mercedes Benz ML320 in which Ms. Dworsky was seated was significantly less than 1.9g.

The acceleration experienced due to gravity is 1g. This means that Ms. Dworsky experiences 1g of loading while in a sedentary state. Therefore, Ms. Dworsky experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[25] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Dworsky's medical records indicated she was 61 inches in height, weighed approximately 120 lbs., and was 41 years old at the time of the subject incident. Ms. Dworsky testified that she was fully stopped and was aware of the oncoming impact, testifying *"before she hit me, I heard squealing of her tires"*. In her Interrogatories, Ms. Dworsky also stated that she *"watched as the defendant collided with the rear of my Mercedes Benz"*. In her testimony, Ms. Dworsky also testified that she *"had my foot as hard as I could on the brake"*, and indicated her *"head went forward in my car, went back and hit the headrest and my seat belt locked tight on me"*. In her Interrogatories, Ms. Dworsky described her kinematics as *"I remember going forward and getting caught in the seatbelt and then coming back and hitting my head on the head rest"*.

This reported forward movement is contrary to the most basic laws of physics. The laws of physics dictate that when the subject Mercedes Benz ML320 was contacted in the rear, it would have been pushed forward causing Ms. Dworsky's seat to move forward relative to her body. This motion would

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19 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

20 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

21 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

22 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

23 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

24 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

25 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

result in Ms. Dworsky moving rearward relative to the interior of the Mercedes Benz ML320 and loading into the seatback structures. Ms. Dworsky's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Dworsky was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Dworsky's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Dworsky would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the Mercedes Benz ML320 and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Dworsky was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[26,27]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Left Shoulder

According to the medical records, a shoulder MRI dated July 31, 2013 reported mild bursal fraying of the supraspinatus tendon and a possible partial-thickness tearing of the distal subscapularis tendon. On February 7, 2014, Ms. Dworsky underwent a left shoulder arthroscopy which diagnosed acromioclavicular joint arthropathy, a partial thickness rotator cuff tear, impingement syndrome, labral tearing, and synovitis. After the surgery on December 4, 2014, another shoulder MRI reported a partial thickness and partial width articular surface tear of the supraspinatus tendon.

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26 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

27 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[28,29,30] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

During the subject incident, Ms. Dworsky's body and extremities would have moved rearward relative to the subject vehicle's interior.[31,32,33,34] This rearward motion would have been supported by the seatback. Ms. Dworsky's upper torso would have loaded into the seat structures and if there was rebound, the seat belt would have engaged Ms. Dworsky's bony left clavicle and pelvis, limiting her motion during the subject incident.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[35,36,37,38] Ms. Dworsky testified she was capable of performing daily activities. These activities would directly load Ms. Dworsky's left shoulder to comparable or greater loads than the subject incident.

The low accelerations in the subject incident and the restraint provided by the seatback, were such that any motion of Ms. Dworsky's left shoulder would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported left shoulder biomechanical failures of Ms. Dworsky cannot be made.

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28 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

29 Melenevsky, Y., Yablon, C.M., Ramappa, A., Hochman, M.G. (2009) "Clavicle and Acromioclavicular Joint Injuries: A Review of Imaging, Treatment, and Complications." Skeletal Radiology. 40:831-842.

30 Simovitch, R., Sanders, B., Ozbaydar, M., Lavery, K., Warner, J.J.P., (2009) "Acromioclavicular Joint Injuries: Diagnosis and Management." J Am Acad Orthop Surg. 4:207-219.

31 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

32 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.

33 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

34 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions*. (No. 2010-01-0067). SAE Technical Paper.

35 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics*. *42*(12), 1840-1849.

36 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics*, *19*(6), 586-594.

37 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).

38 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics*, *40*(10), 2139-2149.

Cervical Spine

According to the medical records, Ms. Dworsky attributes a cervical sprain/strain to the subject incident. A cervical X-ray performed on March 5, 2013 reported no evidence of acute fracture. In a rear impact that produces motion of the subject vehicle, the Mercedes Benz ML320 would be pushed forward and Ms. Dworsky would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2006 Mercedes Benz ML500, a sister vehicle of a 2006-2011 Mercedes Benz ML320, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 32.0 inches in the full down position, and 34.5 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Dworsky revealed she would have a normal seated height of 31.3 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Dworsky's cervical spine would have undergone only a subtle degree of the characteristic response phases.[39] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[40] The cervical loads were within physiologic limits and Ms. Dworsky would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[41,42,43]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[44,45,46,47,48] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[49] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

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39 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

40 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

41 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery, 13(3): 254-260.

42 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

43 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

44 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

45 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

46 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

47 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

48 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

49 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

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The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [50,51,52,53] The available documents reported Ms. Dworsky was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[54]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Dworsky cannot be made.

Thoracic and Lumbar Spine

According to the medical records, Ms. Dworsky attributes a thoracic and lumbar sprain/strain to the subject incident. A thoracic X-ray performed on March 5, 2013 reported no evidence of acute fracture. A lumbosacral X-ray also performed on March 5, 2013 reported straightening as a possible indication of muscle spasms, but no acute fracture. A lumbar MRI from September 23, 2015 identified mild disc bulging at the L3-4 level, and mild disc bulging with an annular fissure formation at the L4-5 level. Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[55] In the absence of this acute biomechanical failure mechanism for lumbar disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[56,57] The primary mechanism for this type of biomechanical failure occurs when a sudden application of a compressive force with associated bending exceeds the limits of the disc tissue strength. [58,59]

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50 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

51 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

52 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

53 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

54 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

55 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

56 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

57 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

58 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

59 Adams, M.A., and Hutton, W.C. (1982). "Prolapsed Intervertebral Disc: A Hyperflexion Injury." Spine. 7: 184-191.

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Dworsky is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Dworsky's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[60,61,62,63] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[64] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[65,66] Ms. Dworsky's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[67,68,69,70,71]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject

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60 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

61 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

62 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

63 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

64 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

65 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

66 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

67 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

68 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

69 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, 7(3), 184-191.

70 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16(7), 549-559.

71 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

incident. [72,73,74,75] Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[76,77] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[78] According to the available documents, Ms. Dworsky was capable of performing daily activities. A segmental analysis of Ms. Dworsky demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[79,80,81]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Dworsky, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

<u>Personal Tolerance Values</u>

According to the available documents, Ms. Dworsky was employed as a senior loan officer. Her medical records indicated that one of her recreational activities was paddle boarding. According to her testimony, Ms. Dworsky also ran flat ground and stairs, and played lacrosse with her children. In her Interrogatories she indicated that her activities also included playing catch, skiing, and golfing, and she was capable of mowing the lawn and grocery shopping. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Dworsky and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[82]

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72 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics, 44*(8), 781-794.

73 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics, 27*(8), 754-758.

74 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics, 46*(3), 511-514.

75 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

76 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

77 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

78 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine, 29*(20), 2319-2329.

79 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

80 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

81 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

82 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes).* (No. 960654). SAE Technical Paper Series.

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It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Dworsky's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Dworsky using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On February 28, 2013, Ms. Tina Dworsky was the seat-belted driver of a 2007 Mercedes Benz ML320 that was stopped on southbound Interstate 5 near Fife, Washington, when contact occurred at low speed between the rear of the subject Mercedes Benz and the front of a 2006 Ford Freestar.
2. The severity of the subject incident was below 6.4 miles-per-hour with an average acceleration less than 1.9g.
3. The acceleration experienced by Ms. Dworsky was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the Mercedes Benz ML320 during the subject incident would tend to move Ms. Dworsky's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Dworsky's claimed left shoulder biomechanical failures. As such, a causal relationship between the subject incident and the left shoulder biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Dworsky's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Dworsky's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

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If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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March 11, 2016

Mark Dietzler, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 Second Avenue
Suite 500
Seattle, WA 98101

Re: *Clevenger, Tauni v. Tegco, Inc.*
ARCCA Case No.: 2107-975

Dear Mr. Dietzler:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Tauni Clevenger. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on May 22, 2012, Ms. Tauni Clevenger was the seat-belted driver of a 1993 Acura Integra. Ms. Michelle Guerra was the driver of a 2012 Mazda 3 traveling directly behind the subject Acura. While the subject Acura was stopped for traffic, contact was made between the front of the incident Mazda 3 and the rear of the subject Acura Integra.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Two (2) color photographic reproductions of the subject 1993 Acura Integra
- One (1) color photographic reproductions of the incident 2012 Mazda 3
- Ohio Security Insurance Company Estimate of Record for the subject 1993 Acura Integra [June 6, 2012]
- Carstar-Barrett's Collision Center, Inc. Estimate of Record for the incident 2012 Mazda 3 [May 23, 2012]
- Collision Analysis & Reconstruction Services, LLC (Ron Snyder) Investigative Report [December 20, 2013]
- Complaint for Personal Injuries and Damages, *Tauni Clevenger vs. Tegco Inc. and John Doe* [May 12, 2015]
- Plaintiff's Answers and Objections to Defendant's First Interrogatories and Requests for Production, *Tauni Clevenger vs. Tegco, Inc. and John Doe* [October 17, 2015]
- Medical Records pertaining to Tauni Clevenger
- VinLink data sheet for the subject 1993 Acura Integra
- Expert AutoStats data sheets for a 1993 Acura Integra
- VinLink data sheet for the incident 2012 Mazda 3
- Expert AutoStats data sheets for a 2012 Mazda 3
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

1. Identify the biomechanical failures that Ms. Clevenger claims were caused by the subject incident on May 22, 2012;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1993 Acura Integra;
3. Determine Ms. Clevenger's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Clevenger's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Clevenger attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
- Post-Traumatic Migraine Complicated by Non-Epileptic Seizures

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 1993 Acura Integra and the incident 2012 Mazda 3 in association with accepted scientific methodologies. [11,12]

The Estimate of Record for the subject 1993 Acura Integra reported damage to the rear bumper cover and aftermarket tow hook, which is consistent with the reviewed photographs (Figure 1). The photographs depicted no significant residual crush to the rear of the subject Acura. Two bolt marks were visible on the top edge of the bumper cover, just left of center. The rear bumper cover, tail lights, trunk lid, and quarter panels were well aligned.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 1993 Acura Integra

The Estimate of Repair for the incident 2012 Mazda 3 indicated damage to the front bumper cover, and noted unrelated dents and scratches. The photographs depicted a minor ding to the right of the lower bumper cover beneath the grille (Figure 2). There was no significant residual crush to the front of the vehicle, and the bumper cover was well aligned with the hood and headlights.

Figure 2: Reproductions of photographs of the incident 2012 Acura Integra

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 1993 Acura Integra revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the rear of an Acura Integra of the same production year would result in significant and visibly noticeable crush across the entirety of the subject Integra's rear structure, with a residual crush of 3.5 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20] The lack of significant structural crush to the entire rear of the subject Acura Integra indicates a collision resulting in a Delta-V significantly below 10 miles per hour. These results are consistent with an energy-based crush analysis to the front of a 2012 Mazda 3.

Additionally, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. This empirical testing was used to perform a damage threshold speed change analysis.[21] The IIHS tested several cars of the same era from the same manufacturer as the subject vehicle as well as vehicles from other manufacturers. In a five mile-per-hour rear impact into a flat barrier the test vehicles sustained damage to the rear bumper covers, rear reinforcement bars, and rear mounting brackets among other parts in some tests. Thus, because the test vehicles in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is more comparable to the severity of the subject incident and places the subject incident speed closer to the test speed of 5 miles-per-hour.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 PC-Crash Collision Software.

20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

21 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour Delta-V is 3.0g and 1.5g for a 10 mile-per-hour Delta-V.[22,23,24,25] By the laws of physics, the average acceleration experienced by the subject Acura Integra in which Ms. Clevenger was seated was significantly less than 3.0g and more consistent with 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Clevenger experiences 1g of loading while in a sedentary state. Therefore, Ms. Clevenger experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [26] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Clevenger's medical records indicated she was 66.5 inches in height, weighed approximately 177 lbs., and was 18 years old at the time of the subject incident. The laws of physics dictate that when the subject Acura Integra was contacted in the rear, it would have been pushed forward causing Ms. Clevenger's seat to move forward relative to her body. This motion would result in Ms. Clevenger moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Clevenger's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Clevenger was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Clevenger's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Clevenger would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Clevenger was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there

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22 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

23 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

24 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

25 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

26 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

<u>Cervical Spine</u>

According to the available documents, Ms. Clevenger attributes a cervical sprain/strain to the subject incident. A cervical X-ray performed May 22, 2012 identified no acute fracture.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Acura Integra would be pushed forward and Ms. Clevenger would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 1989 Honda Civic, a sister vehicle built by the same manufacturer and on the same platform as a 1990-1993 Acura Integra, revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 29.0 inches in the full down position, and 31.5 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Further, the National Highway Traffic Safety Administration (NHTSA) performs impact safety tests for continued performance and safety monitoring of the automotive industry. Testing for a 1990 Acura Integra showed the seated height of a 50th percentile male in the driver's and front passenger's seat was well protected and supported by the seatback components (Figure 3). [29]

27 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

28 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

29 National Highway Traffic Safety Administration (1990). Vehicle Safety Compliance Testing for Occupant Crash Protection, Windshield Mounting, Windshield Zone Intrusion (Partial) and Fuel System Integrity, Report Nos. 208-CAL-90-06, 212-CAL-90-06, 301-CAL-90-06. 1990 Acura Integra.

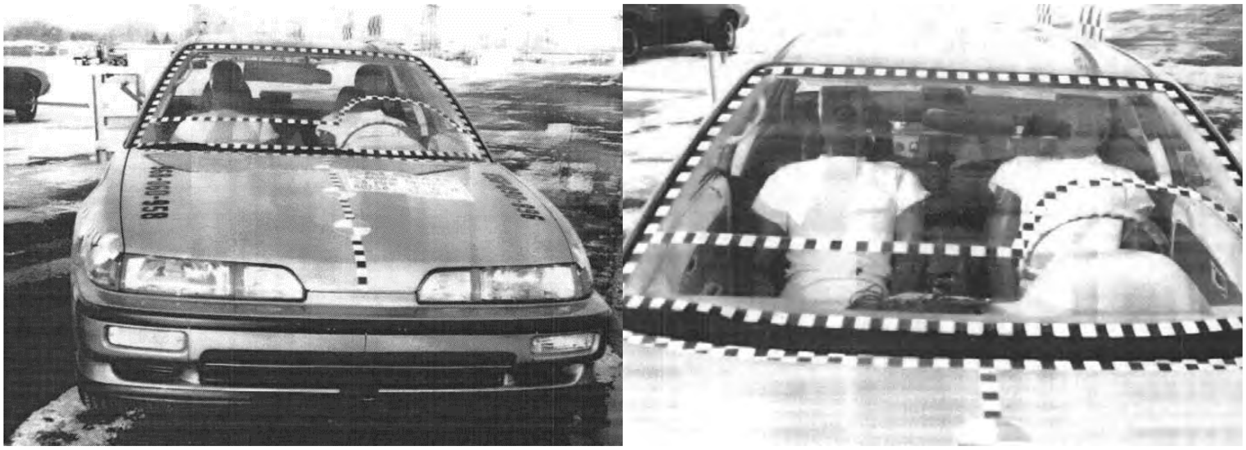

Figure 3: NTHSA 50th percentile males in a 1990 Acura Integra

Performing an anthropometric regression of Ms. Clevenger revealed she would have a normal seated height of 33.9 inches, approximately 0.6 inches shorter than the 50th percentile male ATD. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Clevenger's cervical spine would have undergone only a subtle degree of the characteristic response phases.[30] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[31] The cervical loads were within physiologic limits and Ms. Clevenger would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[32,33,34]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[35,36,37,38,39] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the

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30 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

31 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

32 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

33 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

34 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

35 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

36 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

37 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

38 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

39 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

cervical spine sprain/strain biomechanical failure threshold is 5g.[40] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [41,42,43,44] The available documents reported Ms. Clevenger was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[45]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Clevenger cannot be made.

Thoracic and Lumbar Spine

According to the medical records and available documents, Ms. Clevenger attributes a thoracic and lumbar sprain/strain to the subject incident. Lumbar X-rays performed on May 22, 2012 and August 12, 2013 were both negative, reporting no acute findings.

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Clevenger is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Clevenger's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

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[40] Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

[41] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

[42] Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

[43] Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

[44] Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

[45] Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[46,47,48,49] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[50] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[51,52] Ms. Clevenger's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[53,54,55,56,57]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [58,59,60,61] Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or

46 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

47 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

48 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

49 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

50 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

51 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

52 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

53 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

54 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

55 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

56 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

57 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

58 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

59 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

60 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

61 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

greater than the subject incident.[62,63] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[64] According to the available documents, Ms. Clevenger was capable of performing daily activities. A segmental analysis of Ms. Clevenger demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[65,66,67]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Clevenger, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Post-Traumatic Migraine Complicated by Non-Epileptic Seizures

The claimed failures are not biomechanical in nature, and thus, are not analyzed in this report.

According to the medical records and available documents, Ms. Clevenger attributes post-traumatic migraines complicated by non-epileptic severe seizures to the subject incident. The medical records indicated that Ms. Clevenger did not report striking her head during the subject incident. A CT of Ms. Clevenger's head from October 11, 2012 reported no acute intracranial process. A head MRI performed on October 11, 2012 was reportedly normal. Ms. Clevenger consulted with a neurologist on November 14, 2012 that reported that she believed the seizure symptoms to be *"related to episode where she was anxious or upset"*. A later neurological consultation on March 12, 2014 reported the symptoms were *"still consistent with complicated migraine and not some other more concerning problem"*.

The available documents and medical records indicated Ms. Clevenger was capable of performing normal daily activities. As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[68,69] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly

62 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

63 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

64 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

65 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

66 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

67 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

68 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

69 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

in a chair, while the measured accelerations for a vertical leap were 4.75g. Additional research by Funk et al.[70,71] demonstrated that a simple head shake or plopping into a chair induces accelerations comparable to or greater than the subject incident. Research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[72]

Personal Tolerance Values

According to the available documents, Ms. Clevenger had been employed as a sales associate and a nanny, and worked in a salon. Further, the available documents indicated she was capable of performing activities of daily living. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Clevenger and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[73]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Clevenger's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Clevenger using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 22, 2012, Ms. Tauni Clevenger was the seat-belted driver of a 1993 Acura Integra when contact occurred at low speed between the rear of the subject Acura Integra and the front of a 2012 Mazda 3.

2. The severity of the subject incident was significantly below 10 miles-per-hour, and was more consistent with a 5 mile-per-hour Delta-V, with an average acceleration significantly less than 3.0g and more consistent with 1.5g.

3. The acceleration experienced by Ms. Clevenger was within the limits of human tolerance and comparable to that experienced during various daily activities.

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70 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

71 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

72 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

73 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Clevenger's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Clevenger's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Clevenger's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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March 16, 2016

[redacted]

[redacted]

[redacted]

Dear [redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of [redacted] This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

The available documents reported on March 1, 2009, [redacted] was the seat-belted driver of a 1994 Nissan Altima traveling eastbound on Olympic Drive in Gig Harbor, Washington. [redacted] was the driver of a 2001 Dodge Durango traveling westbound, opposite to the Nissan Altima, on Olympic Drive. The available documents indicated that as the Nissan Altima continued straight along its path, the Dodge Durango turned left in front of the Nissan Altima resulting in contact. The primary points of contact were to the entire front of the Nissan Altima and the passenger's side front of the Dodge Durango. As a result of the contact, both vehicles' frontal airbags deployed and both vehicles were towed from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. 2632359
- One hundred nine (109) color photographic reproductions of the subject 1994 Nissan Altima
- Sixty-three (63) color photographic reproductions of the incident 2001 Dodge Durango
- Farmers Insurance Company of Washington Estimate of Record for the subject 1994 Nissan Altima, March 17, 2009
- Declaration of Steven Stockinger, December 6, 2013
- Amended Declaration of Ted Golson, December 9, 2013
- Declaration of [redacted] February 29, 2016
- Deposition Transcript of [redacted] December 2, 2013
- Deposition Transcript of [redacted] Volume II, December 2, 2013
- Deposition Transcript of [redacted] September 11, 2013
- Deposition Transcript of Virtaj Singh, M.D., February 16, 2016
- Deposition Transcript of Jason G. Attaman, D.O., February 17, 2016
- Medical Records pertaining to [redacted]
- VinLink data sheet for the subject 1994 Nissan Altima
- Expert AutoStats data sheets for a 1994 Nissan Altima
- VinLink data sheet for the incident 2001 Dodge Durango

- Expert AutoStats data sheets for a 2001 Dodge Durango
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the kinematics and contact that [redacted] claims were caused by the subject incident on March 1, 2009;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1994 Nissan Altima;
3. Determine [redacted] kinematic response within the vehicle as a result of the subject incident;

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions and repair estimates of the subject 1994 Nissan Altima and incident 2001 Dodge Durango in association with accepted scientific methodologies. [11,12]

The repair documents for the subject Nissan Altima reported damage including the front bumper cover, hood, right fender, and right apron assembly due to the subject incident. The reviewed photographs of the Nissan Altima depicted airbag deployment and heavy frontal damage skewed toward the right front of the Nissan (Figure 1). The reviewed photographs of the Dodge Durango depicted airbag deployment along with damage to the passenger's side front fender, suspension, bumper, and headlight assembly (Figure 2).

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering, 2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering, 3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 1994 Nissan Altima

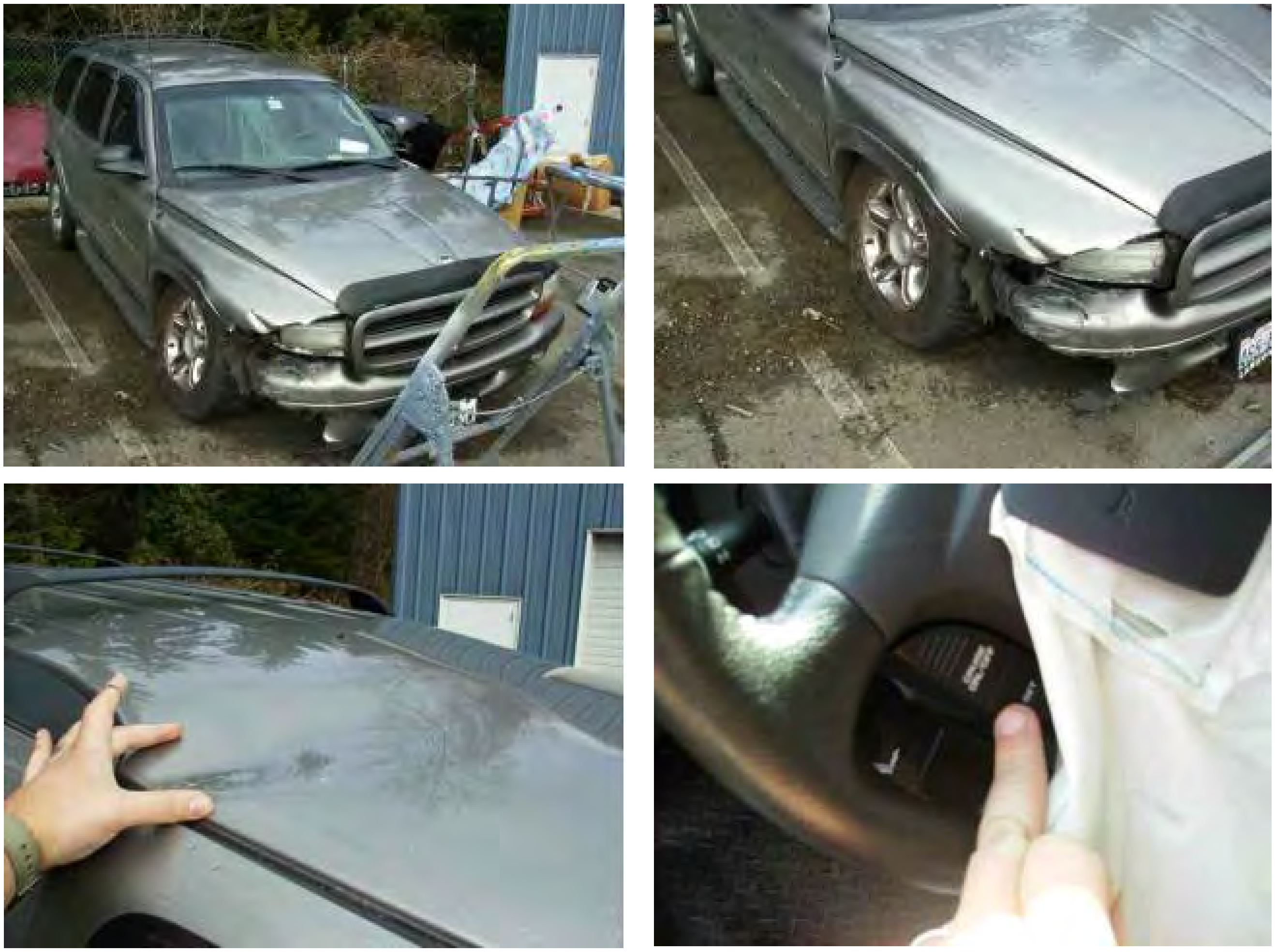

Figure 2: Reproductions of photographs of the incident 2001 Dodge Durango

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 1994 Nissan Altima revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 14 mile per hour flat barrier impact to the right front of a 1994 Nissan Altima would result in significant and similar crush to the subject Nissan Altima, which is consistent with airbag deployment. Automotive manufacturers incorporate airbag control modules that will deploy front airbags when the vehicle experiences a frontal Delta-V of at least 8-14 miles per hour into a rigid barrier. Therefore, the energy crush analysis shows similar deformation would occur in a 14 mile

13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.
14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.
15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.
16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.
17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.
18 EDCRASH, Engineering Dynamics Corp.
19 PC-Crash Collision Software.

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per hour Delta-V impact as compared to the subject incident (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity).[20] Using an acceleration pulse with the shape of a haversine and an impact duration of 70 milliseconds (ms), the average acceleration associated with a 14 mile-per-hour impact is 9.1g.[21,22,23,24]

Kinematic Analysis:

According to the available medical records and testimony, [redacted] was 61 inches in height, weighed approximately 130 lbs., and was 17 years of age at the time of the subject incident. Using the fundamental laws of physics, as well as studies of numerous collisions and crash tests, the subject Nissan Altima's occupant kinematic patterns can be determined.[25,26,27,28,29] The laws of physics dictate that, when contact occurred between the Dodge Durango and the front of the Nissan Altima, the Nissan would have primarily been decelerated longitudinally. Additionally, an occupant moves toward the point of impact, which was the passenger's side front of the subject Nissan Altima. Therefore, this process would have resulted in primarily forward and rightward motion of [redacted] relative to the interior of the Nissan. As the forces were applied during the vehicle contact, the belt retractor would have locked when the accelerations exceeded 0.7g, thereby mitigating the forward motion of the occupants.[30] The lap and shoulder belts would have restrained [redacted] pelvis and torso, respectively, and would have coupled her motion to the subject Nissan Altima. The seat belt would have distributed the restraint loads to the strong bony structures. Further, the airbag deployment would have assisted the seat belt with ride down by limiting body motion and further distributing the loads. The restraint provided by the seat belt system and airbag were such that any motion of [redacted] body would have been limited to well within her occupant space.

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20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

21 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

22 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

23 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

24 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

25 National Highway Traffic Safety Administration (1993). Vehicle Safety Compliance Testing for Occupant Crash Protection, Windshield Mounting, Windshield Zone Intrusion, and Fuel System Integrity. Report No. 208-TRC-94-003. 1994 Nissan Altima.

26 National Highway Traffic Safety Administration (1992). Vehicle Safety Compliance Testing for Occupant Crash Protection, Windshield Mounting, Windshield Zone Intrusion, and Fuel System Integrity. Report No. 208-CAL-93-6. 1993 Nissan Stanza Altima.

27 National Highway Traffic Safety Administration (1992). New Car Assessment Program (NCAP) Frontal Barrier Impact Test. Report No. CAL-90-N07. 1993 Nissan Altima.

28 National Highway Traffic Safety Administration (1995). New Car Assessment Program (NCAP) Frontal Barrier Impact Test. Report No. MGA-96-N004. 1995 Nissan Altima.

29 National Highway Traffic Safety Administration (1994). New Car Assessment Program (NCAP) Frontal Barrier Impact Test. Report No. MGA-94-N009. 1994 Nissan Stanza Altima.

30 Federal Motor Vehicle Safety Standard 209: Seat Belt Assemblies, 49 CFR 571.209.

Discussion:

According to the available testimony and medical records, [redacted] stated that her head struck the windshield due to the impact. However, this reported head impact is in dispute as there are conflicting records. For example, St. Anthony's urgent care, on the day of the subject incident, noted she did not contact her head. This report analyzes if head contact with the windshield was possible.

Photographs of the Nissan Altima were taken by multiple sources at different points in time which appear to depict contradicting damage profiles to the windshield. In his Declaration, Mr. Cory Johnson, noted there were no cracks in the windshield of the Nissan Altima when he performed his inspection. This is supported by [redacted] photographs which do not appear to show windshield damage (Figure 3). The photographs taken by [redacted] do not depict visible windshield damage consistent with a head strike. Further, [redacted] capture minor details as he noted a CD player missing from the trunk and cosmetic blemishes on the interior components. However, photographs taken at a different date depicted a broken windshield, specifically the upper driver's side portion of the windshield near the A-pillar (Figure 4).

Figure 3: Photographs taken by [redacted] of the subject 1994 Nissan Altima

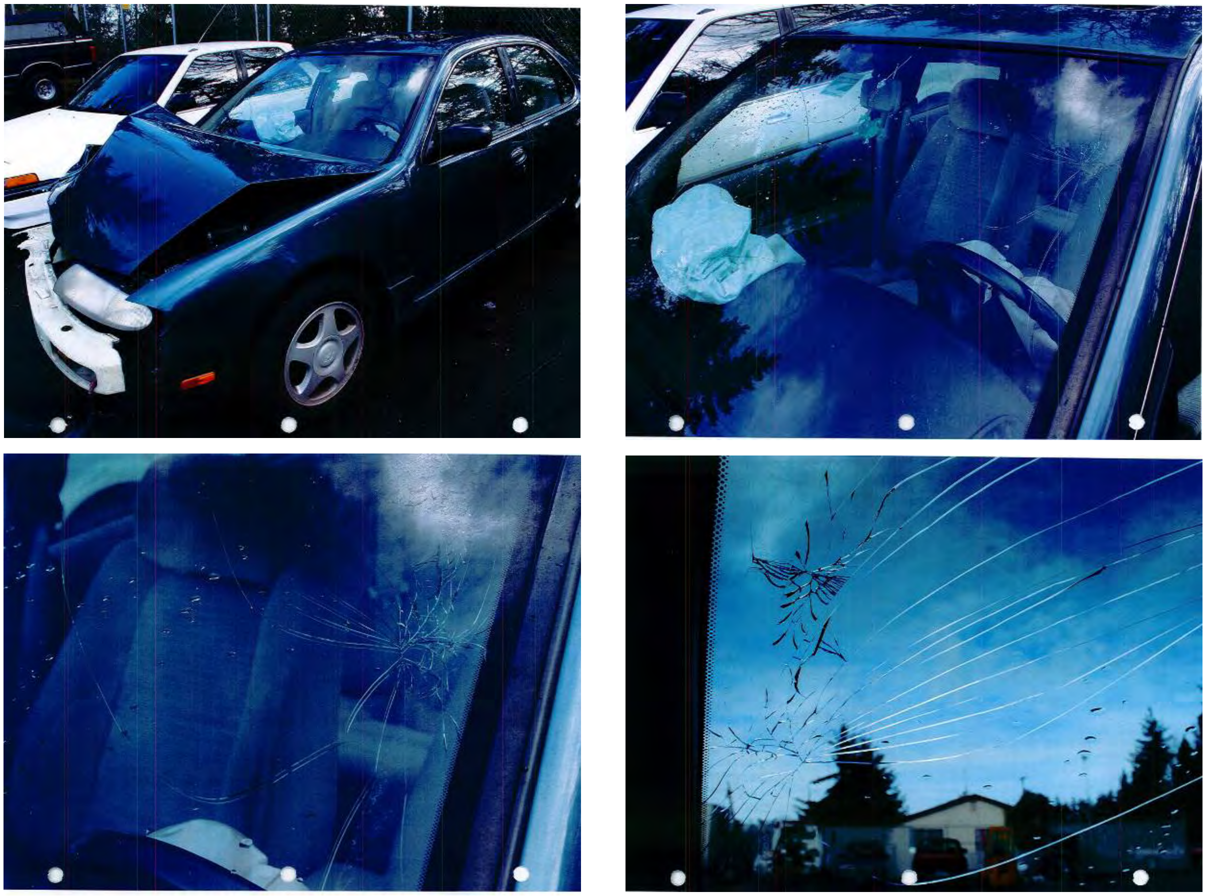

Figure 4: Photographs of subject 1994 Nissan Altima Windshield

Although these photographs depicted multiple fractures of the windshield, the fracture pattern is inconsistent with known head contact fracture patterns.[31,32] The expected pattern would be circular and similar to a bullseye target shape. The initial impact point would be concentrated and the cracks would propagate outward in a circular ring pattern. The cracks in Figure 4 are also in very close proximity to the A-pillar (Note, the photographs in Figure 4 depicted windshield fracture showing damage to the exterior of the A-pillar, which may have resulted in windshield damage). As noted above, [redacted] motion would have been forward and rightward toward the passenger's side of the vehicle, not the driver's side. Figure 4 also depicts multiple points of crack initiation which requires multiple impacts. This is not consistent with known testing of head into windshield impacts. Additionally, Huelke et al. noted that head contact with the windshield was only achieved when the occupants were unbelted. Had [redacted] head in fact contacted the windshield one would also expect contact with the A-pillar. No damage was noted to the interior components of the A-pillar and no abrasions or visible head trauma was noted to [redacted] head from contact with the A-pillar and/or windshield. Note, the right front passenger of the Nissan Altima did not contact the windshield during the subject incident.

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31 Xu, J., Li, Y-B.. (2008). "Study of damage in windshield glazing subject to impact by a pedestrian's head." *J. Automobile Engineering, 222 Part D,* 1-8.

32 Huelke, D.F., et al. (1966). "Facial Injuries due to Windshield Impacts in Automobile Accidents." *Plastic and Reconstruction Surgery, 37(4),* 324-333.

Based upon her testimony, [redacted] stated she sits approximately 12 inches from the steering wheel which she felt was a close seated position. The National Highway Traffic Safety Administration (NHTSA) performs impact safety tests for continued performance and safety monitoring of the automotive industry. NHTSA tested multiple 1993-1995 Nissan Altimas at impact speeds ranging from 30 to 35 mph, well in excess of the subject incident Delta-V of 14 mph. This testing indicated [redacted] seated position was not a close or unusually seated position as the anthropomorphic test devices (ATDs) were seated at 12 to 13 inches from the steering wheel.[33,34,35,36] The seat belt and airbag would limit [redacted] forward excursion and limit her ability to contact frontal interior components. In addition, a closer seated position would further mitigate her ability to contact the windshield as her lower body would contact the dashboard and steering wheel further inhibiting her forward and upward motion. The only contact observed with the windshield during the NHTSA testing was at higher speeds, a more aft seated position, the occupant was unbelted, and the occupant was of greater stature than [redacted]

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On March 1, 2009, [redacted] was the driver of a 1994 Nissan Altima traveling straight on Olympic Drive when contact with a 2001 Dodge Durango occurred.
2. The forces applied to the subject vehicle during the subject incident would tend to move [redacted] body primarily forward. These motions would have been limited and well controlled by the seat belt and airbag safety systems. All motions would be well within normal and protected occupant space.
3. The photographs taken by [redacted] do not depict visible windshield damage consistent with a head strike.

33 National Highway Traffic Safety Administration (1993). Vehicle Safety Compliance Testing for Occupant Crash Protection, Windshield Mounting, Windshield Zone Intrusion, and Fuel System Integrity. Report No. 208-TRC-94-003. 1994 Nissan Altima.

34 National Highway Traffic Safety Administration (1992). Vehicle Safety Compliance Testing for Occupant Crash Protection, Windshield Mounting, Windshield Zone Intrusion, and Fuel System Integrity. Report No. 208-CAL-93-6. 1993 Nissan Stanza Altima.

35 National Highway Traffic Safety Administration (1992). New Car Assessment Program (NCAP) Frontal Barrier Impact Test. Report No. CAL-90-N07. 1993 Nissan Altima.

36 National Highway Traffic Safety Administration (1995). New Car Assessment Program (NCAP) Frontal Barrier Impact Test. Report No. MGA-96-N004. 1995 Nissan Altima.

4. The windshield fractures noted are not consistent with the subject incident and appeared to have occurred at a later date.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

ARCCA, INCORPORATED
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PHONE 877-942-7222 **FAX** 206-547-0759
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April 18, 2016

Gavin Radkey, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Whitaker, Aaron v. Sharon Cratsenberg*
Claim No.: 3384 3804 5039
ARCCA Case No.: 2107-1002

Dear Mr. Radkey:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Aaron Whitaker. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on September 26, 2013, Mr. Aaron Whitaker was the seat-belted driver of a 2013 Toyota Prius traveling on an off ramp from I-5 in Tumwater, Washington. Ms. Sharon Cratsenberg was the driver of a 2002 Mazda Millenia traveling directly behind the Toyota Prius. The available documents indicated that as the Toyota Prius was stopped, contact occurred between the front of the Mazda Millenia and the rear of the Toyota Prius.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eleven (11) color photographic reproductions of the subject 2013 Toyota Prius
- Nine (9) color photographic reproductions of the incident 2002 Mazda Millenia
- Preliminary Estimate for the subject 2013 Toyota Prius, September 30, 2013
- Supplement of Record 1 Summary for the subject 2013 Toyota Prius, October 17, 2013
- Estimate of Record for the incident 2002 Mazda Millenia, July 20, 2015
- Complaint for Personal Injuries, *Aaron L. Whitaker vs. Sharon A. Cratsenberg*, October 27, 2014
- Medical Records pertaining to Aaron Whitaker
- VinLink data sheet for the subject 2013 Toyota Prius
- Expert AutoStats data sheets for a 2013 Toyota Prius
- VinLink data sheet for the incident 2002 Mazda Millenia
- Expert AutoStats data sheets for a 2002 Mazda Millenia
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

1. Identify the biomechanical failures that Mr. Whitaker claims were caused by the subject incident on September 26, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2013 Toyota Prius;
3. Determine Mr. Whitaker's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. Whitaker's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicated Mr. Whitaker attributes the following biomechanical failures to the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic and Lumbosacral Spine
    - Sprain/strain
    - Likely an aggravation to pre-existing facet syndrome

Damage and Incident Severity:

The severity of the incident was analyzed by using the available photographic reproductions and repair estimates of the subject 2013 Toyota Prius and incident 2002 Mazda Millenia in association with accepted scientific methodologies. [11,12]

The repair documents for the subject Toyota Prius reported damage primarily to the rear bumper cover and rear body panel bracket due to the subject incident. The reviewed photographs of the subject Toyota depicted a license plate imprint and scratches/scuffs on the rear bumper cover

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

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(Figure 1). Overall, the photographs did not depict significant crush or misalignment of the rear components on the Toyota Prius.

Figure 1: Reproductions of photographs of the subject 2013 Toyota Prius

The repair documents for the incident Mazda Millenia reported no damage due to the subject incident. The reviewed photographs of the incident Mazda depicted no visible damage (Figure 2). The front bumper cover, license plate, license bracket, headlamps, grille, and hood all remained in proper alignment. Further, there was not significant crush or indentation to the front of the incident Mazda.

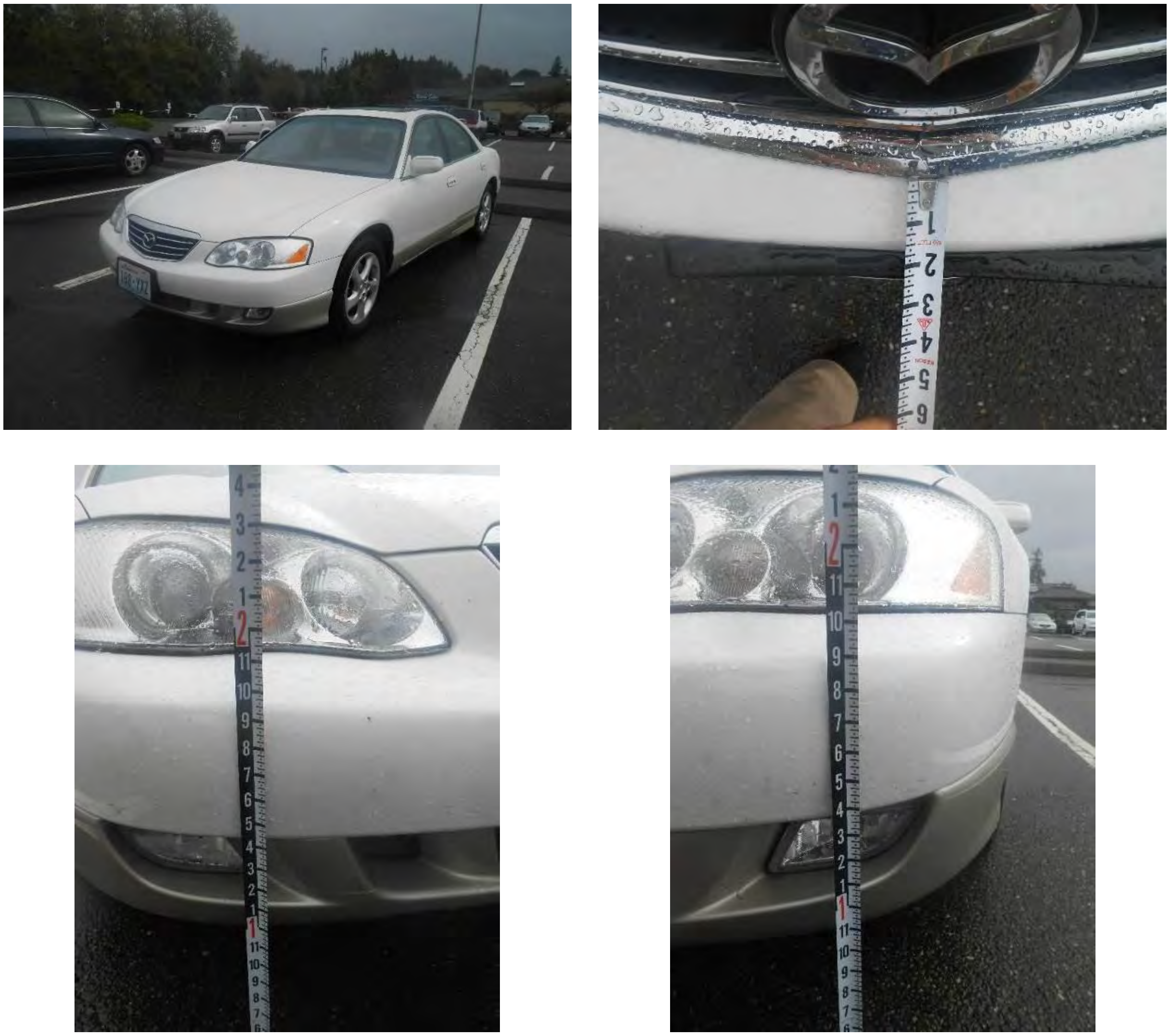

Figure 2: Reproductions of photographs of the incident 2002 Mazda Millenia

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Mazda can be used to resolve the loads sustained by the subject Toyota. That is, the loads sustained by the incident Mazda are equal and opposite to those of the subject Toyota. Damage threshold speed change analyses along with the conservation of linear momentum have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16]

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13 Siegmund, G.P., et al., (1996). U*sing Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*. (No. 960887). SAE Technical Paper.

14 Meriam, J.L., (1952). Mechanics Part II: Dynamics. John Wiley & Sons, New York.

15 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995). *Data and Methods for Estimating the Severity of Minor Impacts*. (No. 950352). SAE Technical Paper.

16 Happer, A.J., Hughes, M.C., Peck, M.D., et al. (2003) *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident 2002 Mazda Millenia, defined by the photographic reproductions, and confirmed by the repair documents, was used to perform a damage threshold speed change analysis. A 1995 Mazda Millenia, production range 1995-2002, was tested in a 5 mile-per-hour frontal full overlap impact into a barrier. The test Mazda sustained damage to the front bumper cover along with the left and right front bumper mounting brackets There was no damage to the incident Mazda Millenia. Thus, because the test Mazda in the IIHS frontal impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed less than 5 miles-per-hour. Accounting for the coefficient of restitution and the conservation of momentum, the subject incident resulted in a Delta-V less than 7 miles-per-hour for the subject Toyota Prius.

Review of the vehicle damage, incident data, published literature, scientific analyses, and my experience indicates an incident resulting in a Delta-V less than 7 miles-per-hour for the subject Toyota Prius. Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 7 mile-per-hour impact is 2.1g.[17,18,19,20] By the laws of physics, the average acceleration experienced by the subject Toyota Prius in which Mr. Whitaker was seated was less than 2.1g.

The acceleration experienced due to gravity is 1g, which means that Mr. Whitaker experiences 1g of loading while in a sedentary state. Therefore, Mr. Whitaker experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Activities such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[21] More dynamic loading activities, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

According to the available medical records Mr. Whitaker was 73 inches in height, weighed approximately 237 lbs., and was 33 years of age at the time of the subject incident. The available documents indicated Mr. Whitaker's vehicle was stopped and he was wearing the available three point restraint at the time of the collision.

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17 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

18 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

19 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

20 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

21 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

The laws of physics dictate that when contact occurred to the rear of the subject Toyota Prius, the vehicle would have been pushed forward causing Mr. Whitaker's seat to move forward relative to his body. This rearward motion would result in Mr. Whitaker moving rearward relative to the interior of the subject vehicle and his body, specifically his entire torso and pelvis, would load into the seatback structures. Any rebound would have been within the range of protection afforded by the available restraint system. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Whitaker would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Whitaker was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

The primary mechanism for this type of biomechanical failure occurs when the head hyperextends over the headrest of the seat. In a rear impact that produces motion of the subject vehicle, the Toyota Prius would be pushed forward and Mr. Whitaker would have moved

22 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
23 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

rearward relative to the vehicle, until his motion was stopped by the seatback and seat bottom. The National Highway Traffic Safety Administration (NHTSA) performs impact safety tests for continued performance and safety monitoring of the automotive industry. Tests for a 2010-2015 model Toyota Prius showed the seated height of a 50th percentile male in the driver's seat was well protected and supported by the head restraint (Figure 3).[24,25]

Figure 3: 50th Percentile Male Anthropomorphic Test Device

Performing an anthropometric regression of Mr. Whitaker revealed he would have a normal seated height of 36.3 inches, while a 50th percentile male has a seated height approximately 1.5 inches shorter. As such, Mr. Whitaker's head and cervical spine would be well supported.[26] The seatback and headrest support and the low vehicle accelerations during the subject incident designate that Mr. Whitaker's cervical spine would have undergone only a subtle degree of the characteristic response phases.[27] The load would have been applied predominantly horizontal to his cervical spine and minimized relevant cervical loads.[28] The available documents indicated Mr. Whitaker did not strike his head. Studies by West showed that head contact did not occur at a Delta-V below 3.3 mph.[29] The cervical loads were within physiologic limits and Mr. Whitaker would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[30,31,32]

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24 National Highway Traffic Safety Administration (2009). New Car Assessment Program (NCAP) Side Impact Test, Report No. NCAPSIDE-MGA-2010-001. 2010 Toyota Prius.

25 National Highway Traffic Safety Administration (2013). New Car Assessment Program (NCAP) Frontal Barrier Impact Test, Report No. NCAP-KAR-14-009. 2014 Toyota Prius.

26 http://www.iihs.org/iihs/ratings/vehicle/v/toyota/prius-4-door-hatchback/2013. Accessed, April 11, 2016

27 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

28 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

29 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

30 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

31 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

32 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[33,34,35,36,37] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[38] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

Mr. Whitaker's records indicated that he was capable of performing normal daily activities prior to the subject incident. The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[39,40,41,42] Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Whitaker cannot be made.

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33 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

34 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

35 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

36 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

37 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

38 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

39 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

40 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

41 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

42 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

43 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Thoracic and Lumbosacral Spine

During an event such as the subject incident, the thoracic and lumbosacral spine of Mr. Whitaker is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Mr. Whitaker's thoracic and lumbosacral spine. The seatback would limit his range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbosacral spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbosacral spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[44,45,46,47] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbosacral biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[48] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[49,50] Mr. Whitaker's thoracic and lumbosacral spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[51,52,53,54,55]

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44 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

45 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

46 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

47 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

48 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

49 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

50 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

51 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

52 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

53 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

54 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

55 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

Mr. Whitaker's records indicated that he was capable of performing normal daily activities. Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [56,57,58,59] Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[60,61] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[62] A segmental analysis of Mr. Whitaker demonstrated that as he lifted objects during daily tasks, the forces applied to his lumbar spine would have been comparable to or greater than those during the subject incident.[63,64,65]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbosacral spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbosacral spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Whitaker, a causal link between the subject incident and claimed thoracic and lumbosacral biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Mr. Whitaker worked as a banker and for FedEx. His job duties included sitting standing, lifting up to 150 lbs., and moving boxes. Between the two jobs Mr. Whitaker worked approximately 60 hours per week. These activities can produce greater movement, or stretch, to the soft tissues of Mr. Whitaker and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed

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56 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

57 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

58 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

59 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

60 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

61 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

62 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

63 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

64 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

65 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[66]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Whitaker's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Whitaker using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On September 26, 2013, Mr. Aaron Whitaker was the driver of a 2013 Toyota Prius stopped in Tumwater, Washington when the subject Toyota was contacted in the rear at a low speed by a 2002 Mazda Millenia.
2. The severity of the subject incident was consistent with 7 miles-per-hour with an average acceleration less than 2.1g.
3. The acceleration experienced by Mr. Whitaker was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Whitaker's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Whitaker's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Whitaker's claimed thoracic and lumbosacral biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbosacral biomechanical failures cannot be made.

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[66] Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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May 24, 2016

Megan Starks, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Wisdom, Leslie v. De-El Enterprises, Inc.*
Claim No.: 23036940
ARCCA Case No.: 2107-1000

Dear Ms. Starks:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures of Leslie Wisdom. The analyses contained in this report are based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, and a Doctorate of Philosophy degree in Biomechanical Engineering. I also held a Post-Doctoral research position studying human biomechanics for an additional two years. I am a member of the Society of Automotive Engineers, American Society of Mechanical Engineers, and the Biomedical Engineering Society.

I have designed and performed experimental tests with both cadaveric and live subjects to study human motion. I have also developed and tested computational and mathematical models of human joints to study kinematics and kinetics during various activities. As such, I am familiar with the theory and application of biomechanical principles as it pertains to human kinematics, joint kinetics, soft-tissue behavior, and biomechanical failure potential.

I have performed automotive safety research, incorporating anthropomorphic test devices and accounting for human variability. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading. I am also familiar with the techniques and processes for evaluating occupant performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). *Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax.* Annual Review of Biomedical Engineering, 2(1), 55-81.

5 King, A.I. (2001). *Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities.* Annual Review of Biomedical Engineering, 3(1), 27-55.

Incident Description:

According to the available documents, on March 24, 2014, Ms. Leslie Wisdom was the seat-belted driver of a 2011 Volkswagen Golf traveling northbound on Interstate 5 near 145th Avenue in Seattle, Washington. Mr. Ramon Rodriguez was the driver of a 2013 Ford E250 Van traveling directly behind the subject Volkswagen. While the Volkswagen was stopped for traffic, contact was made between the front of the incident Ford and the rear of the subject Volkswagen. No airbags were deployed in either vehicle, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. E317164
- Five (5) color photographic reproductions of the subject 2011 Volkswagen Golf
- Seven (7) color photographic reproductions of the incident 2013 Ford E250 Van
- Deposition Transcript of Leslie B. Wisdom, April 20, 2016
- Medical Records pertaining to Leslie Wisdom
- VinLink data sheet for the subject 2011 Volkswagen Golf
- Expert AutoStats data sheets for a 2011 Volkswagen Golf
- VinLink data sheet for the incident 2013 Ford E250 Van
- Expert AutoStats data sheets for a 2013 Ford E250 Van
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community, and is an established approach to evaluate biomechanical failure causation as documented.[6,7,8,9,10] My analyses within the context of this incident were performed incorporating the following steps:

1. Identify the biomechanical failures that Ms. Wisdom claims were caused by the subject incident on March 24, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2011 Volkswagen Golf;
3. Determine Ms. Wisdom's kinematic response within the vehicle as a result of the subject incident;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). *Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax.* Annual Review of Biomedical Engineering, 2(1), 55-81.

9 King, A.I. (2001). *Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities.* Annual Review of Biomedical Engineering, 3(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

4. Define the mechanisms and load magnitudes known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms and load magnitudes were created during the subject incident;
5. Evaluate Ms. Wisdom's personal tolerance in the context of her pre-incident condition to determine within a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the failure mechanisms and load magnitudes that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If the subject incident did not create the failure mechanisms and load magnitudes associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Wisdom attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
- Left Scapula and Shoulder
  - Sprain/strain
- Left Wrist
  - Sprain/strain
- Left Elbow
  - Lateral epicondylitis

Damage and Incident Severity:

The severity of the subject incident was evaluated by analyzing the damage imparted to each of the vehicles involved using the available documentation, along with accepted scientific methodologies.[11,12]

The photographs of the subject 2011 Volkswagen Golf depicted the rear license plate to be bent, along with contact marks and paint chipping to the left side of the rear bumper cover (Figure 1). The outline of a license plate was imprinted to the right of the subject vehicle's rear license plate, and there was a small hole and paint chip also on the right side of the bumper cover. The bumper cover remained in alignment with the tail lights, lift gate, quarter panels, and exhaust pipes. There was no residual crush

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[11] Siegmund, G.P., et al., (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). *Data and Methods for Estimating the Severity of Minor Impacts* (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

to the rear of the vehicle other than the license plate. According to the Shoreline Fire Department incident report, there was *"minimal damage/scratch on bumper"* on the subject Volkswagen.

Figure 1: Reproductions of photographs of the subject 2011 Volkswagen Golf

The photographs of the incident 2013 Ford E250 Van depicted no residual damage (Figure 2). There were scuffs to the front bumper indicative of contact to the left and right sides of the upper portion of on the front bumper. However, the license plate was not bent, and the bumper was in alignment with the grille, head lights, fenders, and hood.

Figure 2: Reproductions of photographs of the incident 2013 Ford E250 Van

The severity of the subject incident was analyzed using multiple methodologies. First, energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photographs and geometric measurements of the subject 2011 Volkswagen Golf revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the rear of a 2011 Volkswagen Golf would result in significant and visibly noticeable crush across the entirety of the subject Volkswagen's rear structure, with a residual crush of 2.25 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20] The lack of significant structural crush to the entire rear of the subject Volkswagen Golf indicates a collision resulting in a Delta-V significantly below 10 miles per hour. This is also supported by a damage threshold speed change analysis to the rear of the subject 2011 Volkswagen Golf.[21]

Further, the incident Ford E250 Van was equipped with a GPS unit that tracked the vehicle's speed prior to and at the time of the subject incident. The GPS records indicate that the incident Ford was traveling less than 6 miles-per-hour immediately prior to the subject incident. Using the conservation of momentum and accounting for restitution, in a worst-case scenario the subject Volkswagen would have experienced a Delta-V of 5.8 miles-per-hour.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour Delta-V is 3.0g, and the average acceleration associated with a 5.8 mile-per-hour Delta-V is 1.7g.[22,23] By the laws of physics, the

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 PC-Crash Collision Software.

20 Tumbas, N.S., Smith, R.A., (1988) *Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View*, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

21 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2011 Volkswagen Tiguan into 2011 Volkswagen Golf, December 2010.

22 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

23 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

average acceleration experienced by the subject Volkswagen Golf in which Ms. Wisdom was seated was significantly less than 3.0g and closer to 1.7g.

For reference, hard braking generates approximately 0.7g, and the acceleration experienced due to gravity is 1g.[24,25] This means that Ms. Wisdom experiences 1g of loading while in a sedentary state. Therefore, Ms. Wisdom experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[26,27,28,29,30,31] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Wisdom's medical records indicated she was approximately 67 inches in height, weighed approximately 130 lbs., and was 43 years old at the time of the subject incident. Ms. Wisdom testified that she was unaware of the oncoming impact and was looking straight ahead. She stated that her foot was on the brake, her right hand on her lap, and her left hand at 7 o'clock on the steering wheel. She further testified that her head *"went up and to the right"*. The records also indicate that Ms. Wisdom's body did not contact the interior of the subject Golf.

The laws of physics dictate that when the subject Volkswagen Golf was contacted in the rear, it would have been pushed forward causing Ms. Wisdom's seat to move forward relative to her body. This motion would result in Ms. Wisdom moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Wisdom's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Wisdom was wearing the available three point restraint, which would have coupled Ms. Wisdom's body to the seat structures. Any rebound would have been within the range of protection afforded by the available restraint system. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Wisdom would have been limited to well within the range of normal physiological limits.

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24 Meriam, J.L. and Kraige, L.G.. (1987). *Engineering Mechanics Volume 2: Dynamics (Second Edition).* New York, John Wiley & Sons.

25 Fricke, Lynn B. (1990). *Traffic Accident Reconstruction. Volume 2 of the Traffic Accident Investigation Manual.* Evanston, Northwestern University Traffic Institute.

26 Mow, V.C. and Hayes, W.C. (1991). *Basic Orthopaedic Biomechanics*. Raven Press, New York.

27 Kutzner, I. et al. (2010). *Loading of the knee joint during activities of daily living measured in vivo in five subjects*. Journal of Biomechanics 43: 2164-2173.

28 Mundermann, A., et al. (2008). *In vivo Knee Loading Characteristics during Acitivities of Daily Living as Measured by an Instrumented Total Knee Replacement*. Journal of Orthopaedic Research 26: 1167-1172.

29 Bergmann, G., et al. (2001). *Hip contact forces and gait patterns from routine activities*. Journal of Biomechanics 34:859-871.

30 Westerhoff, P., et al. (2009). In vivo *measurement of shoulder joint loads during acitivites of daily living*. Journal of Biomechanics 42: 1840-1849.

31 Rohlmann, A., et al. (2014). *Activities of Everyday Life with High Spinal Loads*. PLoS ONE 9(5): e98510.

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Evaluation of Biomechanical Failure Mechanisms:

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part?
2. Did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part?

In order for a biomechanical failure mechanism to be present, both criterion must be met for each biomechanical failure. Therefore, if the subject incident produced loads in both the correct manner and of sufficient magnitude to meet or exceed the tolerance or strength of a body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. However, if either the manner or magnitude of applied loads failed to meet or exceed the tolerance or strength of a body part, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

According to the medical records and other available documents, Ms. Wisdom attributes a cervical sprain/strain to the subject incident. A cervical spine MRI performed February 20, 2015 was reported as normal. A cervical EMG study performed July 24, 2015 reported no evidence of cervical radiculopathy. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching, whereas a strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching.[32] Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

In a rear impact that produces motion of the subject vehicle, the Volkswagen Golf would be pushed forward and Ms. Wisdom would have moved rearward relative to the vehicle until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2011 Volkswagen Golf revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 32.5 inches in the full down position, and 35.5 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Further, the head restraint height does not need to be in line with the height of the seated occupant in order to limit cervical flexion. Performing an anthropometric regression of Ms. Wisdom revealed she would have a normal seated height of 33.7 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Wisdom's cervical spine would have undergone only a subtle degree of the characteristic response phases.[33] The cervical loads were within physiologic limits and Ms. Wisdom would not have been exposed to a cervical spine biomechanical mechanism for failure or exacerbation during the subject incident.[34]

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32 Whiting, W.C. and Zernicke, R.F. (1998). *Biomechanics of Musculoskeletal Injury*. Champaign, Human Kinetics.

33 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). *The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts*. Clinical Anatomy 24: 319-326.

34 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). *Do" whiplash injuries" occur in low-speed rear impacts?* European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6(6), 366-375.

Several researchers have conducted *in vivo* (i.e. live human subject) rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[35,36,37,38] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Additional studies have involved cadavers and anthropomorphic test devices (ATDs).[39,40,41,42,43] At severity levels comparable to that of the subject incident, cadavers did not sustain cervical trauma, and kinematics were inconsistent with the injury mechanism responsible for the discussed cervical injuries. Studies involving ATD's measured cervical response and demonstrated that the forces of the subject incident were within human tolerance, and the injury mechanism responsible for the noted cervical biomechanical failures was not present.

The available documents reported Ms. Wisdom was capable of performing regular daily activities, including working as an actress and playwright, and exercising daily. During common events, the cervical spine experiences accelerations exceeding multiple times what is experienced in a sedentary state without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident.[44] More dynamic activities such as a vertical leap further increase cervical loads.[45,46] Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[47]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident did not create accelerations that exceeded the limits of human tolerance, and were in fact comparable to a range typically seen during activities of daily living. Since neither the manner nor magnitude of applied loads to create a biomechanical failure mechanism occurred, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Wisdom cannot be made.

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35 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

36 West, D.H., Gough, J.P., et al. (1993). *Low Speed Rear-End Collision Testing Using Human Subjects*. Accident Reconstruction Journal, 5, 22-26.

37 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

38 Weiss M.S., Lustick L.S., Gui*delines for Safe Human Experimental Exposure to Impact Acceleration,* Naval Biodynamics Laboratory, NBDL-86R006.

39 Ito, S., Ivancic, P.C., et al., (2004). *Soft Tissue Injury Threshold During Simulated Whiplash: A Biomechanical Investigation* Spine 29: 979-987.

40 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). *An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact* (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

41 Stemper, B.D., and Storvik, S. (2010). *Incorporation of Lower Neck Shear Forces to Predict Facet Joint Injury Risk in Low-Speed Automotive Rear Impacts.* Traffic Injury Prevention 11: 300-308.

42 Yoganandan, N., Pintar, F.A., Stemper, B.D., et al. (2000*). Biomechanics of Human Occupants in Simulated Rear Crashes: Documentation of Neck Injuries and Comparison of Injury Criteria.* Stapp Car Crash Journal 44: 189-204.

43 Ivancic, P.C., Xiao, M., (2011). *Understanding Whiplash Injury and Prevention Mechanisms using a Human Model of the Neck.* Accident Analysis and Prevention 43: 1392-1399.

44 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). *Head and neck loading in everyday and vigorous activities*. Annals of Biomedical Engineering, 39(2), 766-776.

45 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). *The effect of gender and body size on linear accelerations of the head observed during daily activities*. Biomedical Sciences Instrumentation, 42, 25-30.

46 Funk, J.R., Cormier, J.M., et al. (2007). *An Evaluation of Various Neck Injury Criteria in Vigorous Activities.* International Research Council on the Biomechanics of Impact, 233-248.

47 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Thoracic and Lumbar Spine

According to the medical records and other available documents, Ms. Wisdom attributes a thoracic and lumbar sprain/strain to the subject incident. As mentioned previously, a sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching, whereas a strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching.[48] To sustain a strain/sprain type biomechanical failure, significant motion, which produces stretching beyond its normal limits, must occur.

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Wisdom is well supported by the seat and seatback. This support would limit the range of motion to within normal levels, and distribute the restraint forces over the entire torso, reducing both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of significant compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine.[49,50] Therefore, it would not be possible to load the tissue to its physiological limit where biomechanical failure or exacerbation of the tissue would occur.[51,52]

Studies using human volunteers have exposed subjects to rear-end impacts at severities comparable to and greater than the subject incident.[53,54,55,56] Additionally, studies have incorporated ATDs which measured spinal response to rear impact accelerations.[57,58,59] These studies indicate Ms. Wisdom's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.

According to the available documents, Ms. Wisdom was capable of performing daily activities. Specifically, Ms. Wisdom testified she was capable of lifting 20-30 lbs., lifted weights to exercise, and was a recreational skier. Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those

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48 Whiting, W.C. and Zernicke, R.F. (1998). *Biomechanics of Musculoskeletal Injury*. Champaign, Human Kinetics.

49 Gushue, D., B. Probst, et al. (2006). *Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts.* Safety 2006, Seattle, WA, ASSE.

50 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). *An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact* (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

51 Krypton, P., Berleman, U., Visarius H., et al. (1995). *Response of the Lumbar Spine Due to Shear Loading.* 5th Symposium on Injury Prevention Through Biomechanics: 111-126.

52 Brown, T., Hansen, R.J., and Yorra, A.J. (1957). *Some Mechanical Tests on the Lumbosacral Spine with Particular Reference to the Intervertebral Discs: A Preliminary Report.* J Bone Joint Surg Am 39: 1135-1164.

53 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

54 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

55 Weiss M.S., Lustick L.S., Guid*elines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory,* NBDL-86R006.

56 West, D.H., Gough, J.P., et al. (1993). *Low Speed Rear-End Collision Testing Using Human Subjects*. Accident Reconstruction Journal, 5, 22-26.

57 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). *An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact* (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

58 Gushue, D., B. Probst, et al. (2006). *Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts.* Safety 2006, Seattle, WA, ASSE.

59 Gates, D., Bridges, A., Welch, T., et al., (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts* (SAE 2010-01-0141). Warrendale, PA, Society of Automotive Engineers.

resulting from subject incident.[60,61,62,63,64] Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[65,66] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[67] Studies have also demonstrated that lifting objects during daily tasks can produce forces to the lower spine comparable to or greater than those during the subject incident.[68,69]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. The forces created by the incident were within the limits of human tolerance and within the range typically seen in activities of daily living. Since neither the manner nor magnitude of applied loads to create a biomechanical failure mechanism occurred, a causal link between the subject incident and the reported thoracic and lumbar spine biomechanical failures of Ms. Wisdom cannot be made.

Left Shoulder and Left Scapula

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." The scapula, also known as the shoulder blade, is a flat bone that is part of the shoulder and shares attachments with the supraspinatus, infraspinatus, and subscapularis. A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[70,71,72] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

60 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). *Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises*. Ergonomics, 44(8), 781-794.

61 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). *Spinal loads during position changes*. Clinical Biomechanics, 27(8), 754-758.

62 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). *Lifting up and laying down a weight causes high spinal loads*. Journal of Biomechanics, 46(3), 511-514.

63 Morris, J.M., Lucas, D.B., Bresler, B., (1961). *Role of the Trunk in Stability of the Spine*. The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

64 Ng, T.P., Bussone, W.R., Duma, S.M· (2006). *Thoracic and Lumbar Spine Accelerations in Everyday Activities*. Biomedical Sciences Instrumentation 42: 410-415.

65 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). *Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions* (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

66 Rohlmann, A., et al. (2014). *Activities of Everyday Life with High Spinal* Loads. PLoS ONE 9(5): e98510.

67 Kavcic, N., Grenier, S., & McGill, S.M. (2004). *Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises.* Spine, 29(20), 2319-2329.

68 Nordin, M., and Frankel, V.H., (2001). *Basic Biomechanics of the Musculoskeletal System, Third Edition*. Philadelphia, PA, Lippincott Williams & Wilkins.

69 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) *Occupational Biomechanics, Third Edition*, Wiley-Interscience

70 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

71 Melenevsky, Y., Yablon, C.M., Ramappa, A., Hochman, M.G. (2009) *"Clavicle and Acromioclavicular Joint Injuries: A Review of Imaging, Treatment, and Complications."* Skeletal Radiology. 40:831-842.

72 Simovitch, R., Sanders, B., Ozbaydar, M., Lavery, K., Warner, J.J.P., (2009) *"Acromioclavicular Joint Injuries: Diagnosis and Management."* J Am Acad Orthop Surg. 4:207-219.

The available documents indicated Ms. Wisdom was seated facing forward and holding the steering wheel with her left hand. During the subject incident, Ms. Wisdom's body and extremities would have moved rearward relative to the subject vehicle's interior. This rearward motion would have been supported by the seatback. Ms. Wisdom's upper torso would have loaded into the seat structures and if there was rebound, the seat belt would have engaged Ms. Wisdom's bony left clavicle had the accelerations exceeded 0.7g.[73] This interaction with the seat back and seat belt would have limited her motion during the subject incident and not generated the mechanism for biomechanical failure of her shoulders[74].

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[75,76,77,78] Ms. Wisdom testified she was capable of performing daily activities, including lifting 20-30 lbs., and other strenuous daily activities without biomechanical failure. These activities would directly load Ms. Wisdom's shoulders to comparable or greater loads than the subject incident.

The low accelerations in the subject incident and the restraint provided by the seatback, were such that any motion of Ms. Wisdom's left shoulder would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported left shoulder and scapular biomechanical failures of Ms. Wisdom cannot be made.

Left Wrist and Left Elbow

The medical records indicate Ms. Wisdom attributes a left wrist sprain/strain and left elbow epicondylitis to the subject incident. A mechanism for a wrist sprain/strain would only be present if significant relative motion between Ms. Wisdom's ulna/radius and bony hand structure existed during the subject incident.[79] Lateral epicondylitis, also referred to as "tennis elbow", is an inflammation of the ligaments and tendons on the lateral aspect of the elbow joint that most commonly occurs as a result of overuse.[80]

Had there been enough energy to initiate motion, Ms. Wisdom's torso would have moved rearward relative to the subject vehicle's interior, which would have been supported and constrained by the seatback. During this rearward motion Ms. Wisdom's arms would have been unloaded from any interior objects. Specifically, Ms. Wisdom's left wrist and elbow would have been moved away from the steering wheel.[81] The seatback would have distributed any loading across her entire back and

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73 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

74 Lucas, S., et al., (2009). *Analysis of Shoulder Ligament Injury Porential in Automotive Rear-End Impacts* (SAE 2009-01-1203). Warrendale, PA, Society of Automotive Engineers.

75 Murray, I.A., and Johnson, G.R. (2004). *A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks.* Clinical Biomechanics. 19: 586-594.

76 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). *Glenohumeral Contact Forces During Five Activities of Daily Living.* Proceedings of the First Conference of the ISG.

77 Deutch, S.r., et al., (2003) *Elbow joint stability in relation to forced external rotation: An experimental study of the osseous constraint.* Journal of Shoulder and Elbow Surgery 12 (3):287-292.

78 Chadwick, E.K.J., and Nicol, A.C., (2000) *Elbow and wrist joint contact forces during occupational pick and place activities.* Journal of Biomechanics 33: 591-600.

79 Whiting, W.C. and Zernicke, R.F. (1998). *Biomechanics of Musculoskeletal Injury*. Champaign, Human Kinetics.

80 Shiri, R., Viikari-Juntura, E., Varonen, H., and Heliovaara, M., (2006). *Prevalence and Determinants of Lateral and Medial Epicondylitis: A Population Study.* American Journal of Epidemiology, 164(11), 1065-1074.

81 Furbish, C., et al., (2011). *Steering Column Loads and Upper Extremity Motions During Low Speed Rear-End Collisions* (SAE 2011-01-0275). Warrendale, PA, Society of Automotive Engineers.

shoulders. Any rebound would have been limited by the seat belt which would have engaged Ms. Wisdom's bony left clavicle and pelvis. The restraint provided by the seat belt restraint and seatback were such that any motion of Ms. Wisdom's left wrist and elbow would have been limited to well within the range of normal physiological limits.

Activities of daily living are capable of directly loading Ms. Wisdom's left wrist multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[82,83,84,85] These data demonstrate that the left wrist and elbow forces and accelerations of the subject incident did not exceed Ms. Wisdom's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the left wrist and elbow. Finally, the forces created by the incident were well within the limits of human tolerance for the left wrist and elbow and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Wisdom, a causal link between the subject incident and claimed left wrist and elbow biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Ms. Wisdom was working as an actress, and was also a playwright and director. In describing her work, Ms. Wisdom testified that *"there was some significant physical activity required"*, specifically lifting 20-30 lbs. set pieces and moving props. She further indicated that her hobbies included hiking, cooking, daily exercising (aerobics, weights, and cardio), skiing, and grocery shopping. These activities can produce greater movement and stretch to the soft tissues of Ms. Wisdom, and produce comparable or greater forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the employed methodologies and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Wisdom's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Wisdom using peer-reviewed and generally-accepted methodologies.

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82 Murray, I.A., and Johnson, G.R. (2004). *A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks.* Clinical Biomechanics. 19: 586-594.

83 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). *Glenohumeral Contact Forces During Five Activities of Daily Living.* Proceedings of the First Conference of the ISG.

84 Deutch, S.r., et al., (2003) *Elbow joint stability in relation to forced external rotation: An experimental study of the osseous constraint.* Journal of Shoulder and Elbow Surgery 12 (3):287-292.

85 Chadwick, E.K.J., and Nicol, A.C., (2000) *Elbow and wrist joint contact forces during occupational pick and place activities.* Journal of Biomechanics 33: 591-600.

Conclusions

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On March 24, 2014, Ms. Leslie Wisdom was the seat-belted driver of a 2011 Volkswagen Golf that was stopped on northbound Interstate 5 in Seattle, Washington, when the subject Volkswagen Golf was contacted in the rear at low speed by a 2013 Ford E250 Van.
2. The severity of the subject incident was significantly less than 10 miles-per-hour with an average acceleration of 3.0g, and more consistent with 5.8 miles-per-hour with an average acceleration of 1.7g.
3. The acceleration experienced by Ms. Wisdom was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Wisdom's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Wisdom's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Wisdom's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Wisdom's claimed left shoulder and scapula biomechanical failures. As such, a causal relationship between the subject incident and the left shoulder and scapula biomechanical failures cannot be made.
8. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Wisdom's claimed left wrist and elbow biomechanical failures. As such, a causal relationship between the subject incident and the left wrist and elbow biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This report is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Adam J. Cyr, Ph.D.
Senior Biomechanist

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June 3, 2016

EXHIBIT A

Amy Freiman, Esquire
Hills Legal Group Ltd
N19 W24075 Riverwood Drive
Suite 333
Waukesha, WI 53188-1170

Re: *Trice-Allen, Sandra v. Thomas Quinn, Secura Ins., American Family Ins. Co., Aurora Accountable Network, and Aurora Health Care, Inc., and Aetna Life Ins.*
Claim No.: P0155056
File No.: 18.7265
ARCCA Case No.: 4961-002

Dear Ms. Freiman:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Sandra Trice-Allen. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.
2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.
3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.
4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.
5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on January 26, 2013, Mr. Willie Gage was the seat belted driver of a 2003 Hyundai XG350 backing from a parking space in a Menard's parking lot located at 6800S 27th St in Oak Creek, Wisconsin. Ms. Sandra Trice-Allen was the seat-belted right rear passenger of the Hyundai XG350. Mr. Thomas Quinn was the driver of a 2004 GMC Yukon backing from a parking space directly across from the Hyundai. According to the available documents, both vehicles continued along their respective paths of travel. As a result, contact occurred between the rear driver's side corner of the incident GMC and the rear passenger's side of the subject Hyundai. No airbags were deployed as a result of the impact, and neither vehicle was towed from the scene of the incident.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Wisconsin Motor Vehicle Accident Report, Accident No. 13-002660
- Seventeen (17) color photographic reproductions of the subject 2003 Hyundai XG350
- Eleven (11) color photographic reproductions of the incident 2004 GMC Yukon
- Repair Estimate for the subject 2003 Hyundai XG350, February 5, 2013
- Repair Supplement 1 for the subject 2003 Hyundai XG350, February 12, 2013
- Repair Supplement 2 for the subject 2003 Hyundai XG350, February 18, 2013
- Preliminary Estimate for the incident 2004 GMC Yukon, March 14, 2013
- Recorded Statement Transcript of Willie Gage, January 29, 2013
- Recorded Statement Transcript of Thomas G. Quinn, February 5, 2013
- Deposition Transcript of Willie Gage, *Sandra Trice-Allen vs. Thomas Quinn, et al., and Aurora Health Care, Inc., et al.*, May 12, 2016
- Deposition Transcript of Geraldine Allen-Gage, *Sandra Trice-Allen vs. Thomas Quinn, et al., and Aurora Health Care, Inc., et al.*, May 12, 2016
- Deposition Transcript of Sandra Trice Allen, *Sandra Trice-Allen vs. Thomas Quinn, et al., and Aurora Health Care, Inc., et al.*, May 2, 2016
- Medical Records pertaining to Sandra Trice-Allen
- VinLink data sheet for the subject 2003 Hyundai XG350
- Expert AutoStats data sheets for a 2003 Hyundai XG350
- VinLink data sheet for the incident 2004 GMC Yukon
- Expert AutoStats data sheets for a 2004 GMC Yukon

- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Trice-Allen claims were caused by the subject incident on January 26, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle;
3. Determine Ms. Trice-Allen's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident.
5. Evaluate Ms. Trice-Allen's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Ms. Trice-Allen attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic and Lumbar Spine
  - Sprain/strain

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

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- Right Shoulder
    - Significant fraying of the undersurface of the rotator cuff in the critical zone
    - Near full-thickness tear of the rotator cuff

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2003 Hyundai XG350 and incident 2004 GMC Yukon in association with accepted scientific methodologies.[11,12]

The repair documents for the subject Hyundai indicated damage primarily to the right rear door outer panel, right quarter panel, right rear door shell, right inner door jamb, and pulls were performed on right inner door area. The available photographs depicted deformation to the right quarter panel and right rear passenger door (Figure 1).

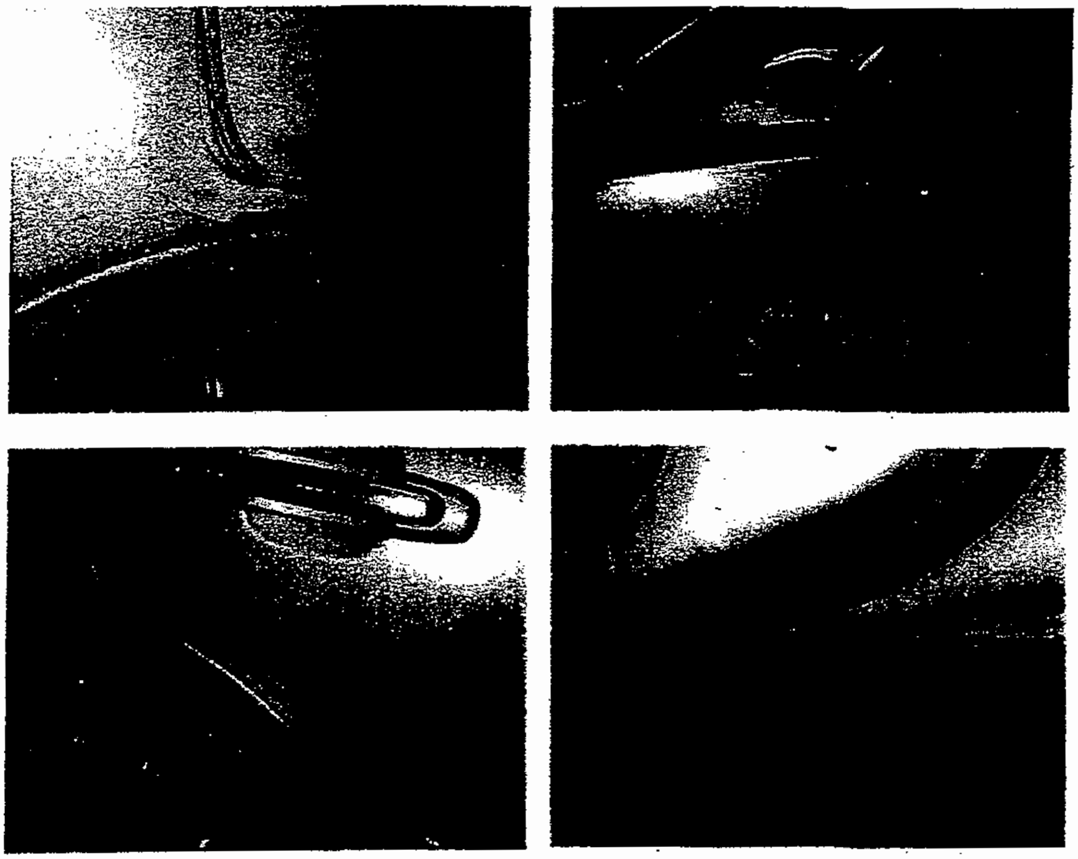

Figure 1: Reproductions of the subject 2003 Hyundai XG350

[11] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

[12] Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

The repair documents for the incident GMC indicated damage primarily to the rear step bumper, rear step bumper pad, and left/right rear bumper step pad. The available photographs depicted a dent in the left rear corner of the bumper bar and a gouge in the rear step pad (Figure 2).

Figure 2: Reproductions of the incident 2004 GMC Yukon

Evaluating a worst case scenario, the damage to the incident 2004 GMC Yukon, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13,14] The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The IIHS tested a 2001 Chevrolet Silverado in a 5 mile-per-hour rear impact into a flat barrier.[15] Utilizing the vehicle identification number (VIN) for the subject GMC Yukon and IIHS tested Chevrolet Silverado, it was determined both vehicles utilize the similar rear bumper assembly components such as the rear step bumper, rear bumper reinforcement, rear bumper step pad, and the left/right rear bumper step pad (Figure 3). The test Chevrolet Silverado sustained damage to the rear reinforcement/hitch plate/step bumper, left and right rear outer bumper mounting braces, left and right rear frame rail ends as well as body damage. The primary damage to the incident GMC Yukon was to the rear step bumper, rear step bumper pad, and left/right rear

13 Siegmund, G.P., et al., (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*. (No. 960887). SAE Technical Paper.

14 Happer, A.J., Hughes, M.C., Peck, M.D., et al. (2003) *Practical Analysis Methodology for Low Speed Vehicle Collisions Involving Vehicles with Modern Bumper Systems*. (No. 2003-01-0492). SAE Technical Paper.

15 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2001 Chevrolet Silverado, April 2001.

bumper step pad. Thus, because the test Chevrolet Silverado in the IIHS rear impact test sustained greater damage than the incident GMC Yukon, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject incident speed at or below 5 miles-per-hour.

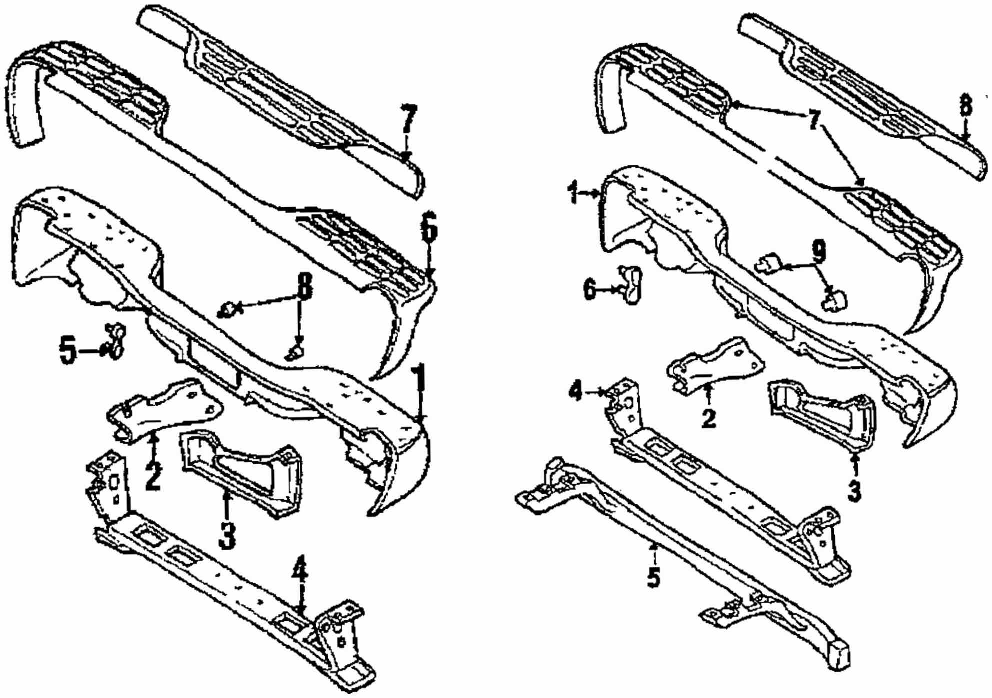

Figure 3: Bumper Assembly Diagrams, GMC Yukon (left) and Chevrolet Silverado (right)

Further, it is known based upon the available testimonies and evidence that the Menard's parking lot was utilizing angled parking as shown in Figure 4. As such and due to the slight dragging damage along the subject Hyundai's rear passenger door onto the rear quarter panel indicates that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces, which is consistent with a sideswipe event.[16] This is consistent with Mr. Gage's testimony that the contact was *"glancing"* and both vehicles were at an angle.

16 Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

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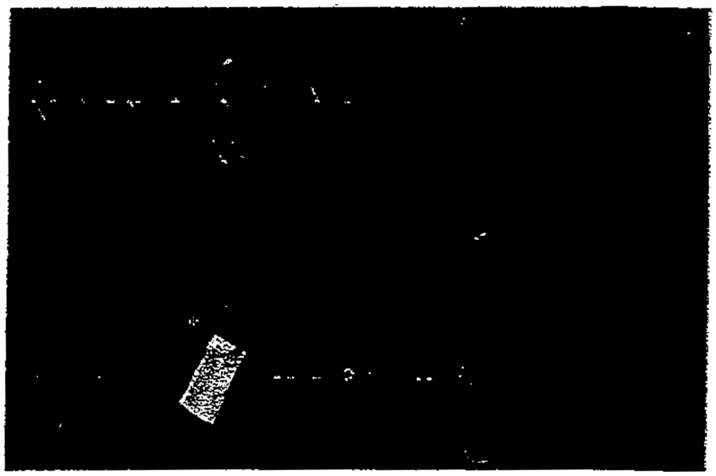

Figure 4: Google Image of Menard's Parking

The laws of physics dictate that the longitudinal force exerted to the subject Hyundai XG350 convertible was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the subject Hyundai as a result of the sideswipe event was less than 1.0g.[17] Using an acceleration pulse with the shape of a haversine and duration of 200 milliseconds,[18] the Delta-V associated with the subject incident is 2.3 mph. Therefore, the subject Hyundai was exposed to a Delta-V of less than 2.3 mph with peak acceleration less than 1.0g. Additionally, the lateral accelerations experienced by the subject Hyundai XG350 would have been less than 0.8 to 0.9g, as there is no indication in the available documents that the Hyundai XG350 was pushed along the aisle way. The available documents indicated the vehicles stopped where contact occurred and were blocking the aisle way after the incident occurred. Comparatively, hard braking of the Hyundai XG350 generates approximately 0.7g to 0.8g during the event.

The acceleration experienced due to gravity is 1g. This means that Ms. Trice-Allen experiences 1g of loading while in a sedentary state. Therefore, Ms. Trice-Allen experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[19] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

17 Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions, (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

18 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

19 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

Kinematic Analysis:

According to the available medical records, Ms. Trice-Allen was 50 years old, 62 inches tall and weighed approximately 168 lbs. Ms. Trice-Allen testified that she was seated primarily upright and was unaware of the impending collision. She testified that she does not remember if her body contacted the interior of the subject vehicle and does not remember contacting any parts of the subject vehicle.

The laws of physics dictate that had there been enough energy transferred to initiate motion, the sideswipe event would have caused the subject Hyundai XG350 to accelerate rearward longitudinally and accelerate laterally leftward. Scientific literature indicates that provided the low accelerations of the event, less than 1.0g, no significant occupant motion would have occurred.[20,21] ARCCA, Incorporated has conducted experiments that exposed motor vehicles to low severity contact events, less than or comparable to 1.0g. These experiments included tracking the movement of human volunteers and anthropomorphic test devices (ATDs) during the testing. Results demonstrated that neither the human volunteers nor the ATDs experienced any significant motion relative to the vehicle's interior. If occupant motion were assumed to have occurred during the subject incident, the laws of physics and results from previous studies[22,23] dictate that Ms. Trice-Allen would have tended to move slightly forward and rightward relative to the vehicle's interior. This motion would have been controlled and supported by the friction generated at her seat bottom, the interior door components and the three point restraint. Specifically, the three-point restraint would have locked during the subject incident had the acceleration exceeded 0.7g and limited her forward body excursion.[24] Provided the low accelerations of the subject incident, and the supports described, the bodily response of Ms. Trice-Allen would have been limited to well within normal physiological limits

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Trice-Allen was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[25,26]

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20 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

21 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

22 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

23 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

24 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

25 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

26 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

As described previously, the sideswipe event would have caused the subject Hyundai XG350 to accelerate rearward longitudinally and accelerate slightly leftward. Scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, less than 1.0g, no significant occupant motion would have occurred.[27,28] If occupant motion were assumed, Ms. Trice-Allen would have moved forward and rightward relative to the vehicle's interior.[29,30] This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Hyundai XG 350. Ms. Trice-Allen's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[31] As a result, Ms. Trice-Allen's cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[32]

27 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

28 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

29 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

30 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

31 Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

32 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

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Human volunteers have been exposed to frontal and lateral impact accelerations at levels comparable to, and greater than that of the subject incident.[33,34,35,36,37,38,39,40,41,42,43] Participants moved toward the point of impact while their response was controlled by the three-point restraint, seat structures, and vehicle interior components. None of the volunteers reported cervical trauma in response to this testing. Further research has exposed cadavers to impact accelerations within the biomechanical failure range.[44,45] These results demonstrated that the accelerations during the subject incident were maintained well within human tolerance as none of the cadaveric testing resulted in cervical trauma at acceleration levels consistent with the subject incident. The accelerations during the subject incident were maintained within published guidelines for safe human exposure to frontal and lateral impact accelerations.[46] In addition, these studies demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[47,48] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Research by Funk et al.[49] demonstrated that a simple head shake or a self-inflicted hand strike to the head induces accelerations comparable to or greater than the subject incident. Ms. Trice-Allen testified she performed daily activities without biomechanical failure prior to the subject incident. These activities would have generated cervical forces that were comparable to and greater than those of

33 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

34 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

35 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

36 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

37 Matsushita, T., Sato, T.B., Hirabayashi, K., et al. (1994). X-ray Study of the Human Neck Motion Due to Head Inertia Loading (SAE 942208). Warrendale, PA. Society of Automotive Engineers.

38 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

39 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

40 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

41 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

42 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

43 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

44 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

45 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

46 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

47 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

48 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

49 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

the subject incident.[50,51,52,53] These data demonstrate that the cervical forces of the subject incident did not exceed Ms. Trice-Allen's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Trice-Allen cannot be made.

Thoracic and Lumbar Spine

In this type of collision, the motion of Ms. Trice-Allen's thoracic and lumbar spine would have been well supported and constrained. Again, scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, less than 1.0g, no significant occupant motion would have occurred.[54,55] Provided sufficient energy to overcome Ms. Trice-Allen's muscle reaction forces, her body would have moved forward and rightward relative to the Hyundai XG350's interior. As described previously, Ms. Trice-Allen testified she was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited her forward body excursion.[56] The seat belt would have primarily engaged Ms. Trice-Allen's bony right clavicle and pelvis distributing the load over her entire torso. Therefore, Ms. Trice-Allen's thoracic and lumbar spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of Ms. Trice-Allen's thoracic and lumbar spine during the subject incident would have been limited to within normal physiologic limits.

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50 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" Biomedical Sciences Instrumentation 42: 25-30.

51 Vijayakumar, V., Scher, I., Gloeckner, D.C., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA. Society of Automotive Engineers.

52 Choi, H., and Vanderby, R. (2000). "Muscle Forces and Spinal Loads at C4/5 Level During Isometric Voluntary Efforts." Medicine & Science in Sports & Exercise 830-838.

53 Moroney, S.P., Schultz, A.B., and Miller, J.A.A. (1988). "Analysis and Measurement of Neck Loads." Journal of Orthopaedic Research 6: 713-720.

54 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

55 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

56 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

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Researchers have frequently exposed human volunteers to both frontal and lateral impact accelerations at levels comparable to and greater than that of the subject incident.[57,58,59,60,61,62,63,64] No thoracic or lumbar biomechanical failures were reported and kinematics documented. Additionally, occupant kinematics were inconsistent with the biomechanical failure mechanism responsible for the thoracic and lumbar failures. Published guidelines for safe human exposure to frontal and lateral impacts are consistent with the results from these studies.[65] These data provide support for the conclusions described previously regarding Ms. Trice-Allen's response to the subject incident. In addition, these data demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

The subject incident had a peak acceleration below 1.0g. Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[66] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[67] Studies by Rohlmann et al.[68,69,70] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not

57 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

58 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

59 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

60 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

61 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

62 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

63 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

64 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

65 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

66 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation,* 42:410-415.

67 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

68 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics, 44*(8), 781-794.

69 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics, 27*(8), 754-758.

70 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics, 46*(3), 511-514.

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create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Trice-Allen, a causal link between the subject incident and claimed thoracic and lumbar spine biomechanical failures cannot be made.

Right Shoulder

According to a right shoulder operative report, dated December 17, 2014, there were findings consistent with an acromioclavicular (AC) joint degenerative joint disease, other minor degenerative changes, significant fraying of the undersurface of the rotator cuff in the critical zone, and a near full-thickness tear of the rotator cuff.

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis and teres minor are the four muscles of the "rotator cuff." The supraspinatus runs laterally from the posterosuperior scapula to the head of the humerus. The supraspinatus tendon creates the connection between the supraspinatus muscle and the humeral head.[71] The biomechanical failure mechanism required to cause a supraspinatus tear involves loading through the upper arm that forcibly presses the humeral head against the acromion and coracoacromial ligament in the superior-posterior aspect of the glenoid fossa.[72,73,74] The AC joint is formed by the lateral end of the clavicle and the medial end of the acromion. The joint is stabilized by the coracoclavicular ligaments and AC capsule. An acromioclavicular sprain/strain refers to inflammation and over stretching of these ligaments and soft tissues surrounding the AC joint. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[75,76,77] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

The laws of physics and results from previous studies dictate that Ms. Trice-Allen, would likely have no movement, but any minor movement would have tended to be slightly forward and rightward relative to the vehicle's interior. [78,79] This motion would have been controlled and supported by the friction generated at her seat bottom, the interior door components and the three point restraint. Specifically, the three-point restraint would have locked during the subject incident had the acceleration exceeded 0.7g and limited her forward body excursion.[80] Additionally, Ms. Trice-Allen testified she does not remember contacting any parts of the subject Hyundai during the subject incident. These actions do not create the biomechanical failure mechanisms required

71 Netter, F.H. (1989) Atlas of Human Anatomy, Ciba-Geigy Corporation
72 Giaroli, E.L., Major, N.M., et al. (2005). "MRI of Internal Impingement of the Shoulder." American Journal of Radiology 185: 925-929.
73 Weaver, J.K., (1987). "Skiing-related Injuries to the Shoulder." Clinical Orthopaedics and Related Research 216: 24-28.
74 Warner, J.J., Higgins, L., Parsons, I.M., et al., (2001). "Diagnosis and Treatment of Anteriorsuperior Rotator Cuff Tears." Journal of Shoulder and Elbow Surgery 10(1): 37-46.
75 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.
76 Melenevsky, Y., Yablon, C.M., Ramappa, A., Hochman, M.G. (2009) "Clavicle and Acromioclavicular Joint Injuries: A Review of Imaging, Treatment, and Complications." Skeletal Radiology. 40:831-842.
77 Simovitch, R., Sanders, B., Ozbaydar, M., Lavery, K., Warner, J.J.P., (2009) "Acromioclavicular Joint Injuries: Diagnosis and Management." J Am Acad Orthop Surg. 4:207-219.
78 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.
79 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.
80 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

for a right shoulder biomechanical failure. The loading and kinematics of Ms. Trice-Allen's right shoulder was well within the limits of human tolerance and physiological motion.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[81,82,83,84] Ms. Trice-Allen testified she was capable of performing daily activities without biomechanical failure. These activities would directly load Ms. Trice-Allen's right shoulder to comparable or greater loads than the subject incident.

The low accelerations in the subject incident and the restraint provided by the seatback, were such that no motion would be expected and that any minor motion of Ms. Trice-Allen's right shoulder would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported right shoulder biomechanical failures of Ms. Trice-Allen cannot be made.

Personal Tolerance Values

According to the testimony and other available documents, Ms. Trice-Allen worked a desk job at the time of the subject incident. She testified that she was capable of cooking, laundry, carrying groceries and being socially active. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Trice-Allen and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[85]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Trice-Allen's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Trice-Allen using peer-reviewed and generally-accepted methodologies.

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81 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics, 42*(12), 1840-1849.

82 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics, 19*(6), 586-594.

83 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).

84 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics, 40*(10), 2139-2149.

85 Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

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Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On January 26, 2013, Ms. Sandra Trice-Allen was the seat belted right rear passenger of a 2003 Hyundai XG350 that was contacted in the rear passenger's side by a 2004 GMC Yukon at a low-speed.
2. The severity of the subject incident was consistent with a Delta-V less than 2.3 miles-per-hour with peak acceleration less than 1.0g for the subject 2003 Hyundai XG350 in which Ms. Trice-Allen was seated.
3. The acceleration experienced by Ms. Trice-Allen was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. Had the forces of the subject incident been sufficient to overcome the muscle reaction forces, Ms. Trice-Allen's body forward and rightward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Trice-Allen's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Trice-Allen's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic, lumbar and lumbosacral biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Trice-Allen's claimed right shoulder biomechanical failures. As such, a causal relationship between the subject incident and the right shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
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June 6, 2016

[redacted]

[redacted]

Dear [redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of [redacted] This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the testimony and other available documents, on November 25, 2014, [redacted] was the seat-belted driver of a 2013 Hyundai Veloster traveling northbound on 192nd Avenue in Vancouver, Washington. [redacted] was the driver of a 1997 Toyota Camry traveling one vehicle ahead of the subject Hyundai. [redacted] was the front passenger in the incident Toyota. The documents indicate that the subject Hyundai turned into the adjacent turn lane to the left, passing one car before approaching the incident Toyota. As the subject Hyundai began passing the incident Toyota on the left, the Toyota began to turn in to the turn late, contacting the right side of the subject Hyundai. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Two (2) color photographic reproductions of the subject 2013 Hyundai Veloster
- Allstate Insurance Company Estimate of Record for the subject 2013 Hyundai Veloster [December 2, 2014]
- Complaint, [redacted] [April 4, 2016]
- Recorded Statement Audio File of [redacted] [December 1, 2014]
- Recorded Statement Audio File of [redacted] [December 6, 2014]
- Medical Records pertaining to [redacted]
- VinLink data sheet for the subject 2013 Hyundai Veloster
- Expert AutoStats data sheets for a 2013 Hyundai Veloster
- Expert AutoStats data sheets for a 1997 Toyota Camry
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

1. Identify the biomechanical failures that [redacted] claims were caused by the subject incident on November 25, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle [redacted] was occupying;
3. Determine [redacted] kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident.
5. Evaluate [redacted] personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, [redacted] attributes the following biomechanical failures as a result of the subject incident:

- Right Shoulder
  - Sprain/strain
  - Adhesive capsulitis
- Left Hip
  - Possible labral tear vs. tendinitis
- Right Knee
  - Sprain/strain
  - Lateral patellar compression syndrome
- Cervical/Thoracic/Lumbar/Sacral Spine, Sacroiliac Joint
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the subject 2013 Hyundai Veloster in association with accepted scientific methodologies.[11,12]

The Estimate of Record for the subject Hyundai Veloster reported damage primarily to the right quarter panel, right fender, right front and rear door shells, right front and rear wheels, and rear bumper cover, which is consistent with the available photographs (Figure 1). The photographs depicted scrapes down the right side of the vehicle, extending from the right fender to the right quarter panel and edge of the rear bumper cover. The right fender had residual crush just behind the right front wheel.

Figure 1: Reproductions of the subject 2013 Hyundai Veloster

Scientific analyses of the photographs and geometric measurements of the vehicles along with the available testimony, identified that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces. As such, the subject incident was consistent with a sideswipe event.[13] The laws of physics dictate that the lateral force exerted to the right side of the subject Hyundai Veloster was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the incident as a result of the sideswipe event was less than 2.5g.[14] Using an acceleration pulse with the shape of a haversine and duration of 200 milliseconds,[15] the Delta-V associated with the subject incident is 5.3 mph. The lateral forces to the Hyundai Veloster associated with the subject incident were calculated to be insignificant.

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that [redacted] experiences 1g of loading while in a sedentary state. Therefore, [redacted] experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of

11 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

12 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

13 Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

14 Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions, (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

15 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[16] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

The available documents indicate [redacted] was bracing during the subject incident, with her left hand on the steering wheel and her right hand on the center arm rest. They further indicate her left foot was on the floor, and her right foot was on the gas. [redacted] indicated that her right knee and shoulder struck the middle console, and her right knee may have also made contact with the dashboard. She also indicated she was looking straight, sitting upright, and slightly leaning right.

The laws of physics dictate that had there been enough energy transferred to initiate motion, the sideswipe event would have caused the subject Hyundai to decelerate longitudinally and accelerate slightly leftward. Scientific literature indicates that provided the low accelerations of the event, little occupant motion would have occurred.[17,18] ARCCA, Incorporated has conducted experiments that exposed motor vehicles to low severity contact events similar to the subject incident. These experiments included tracking the movement of human volunteers and anthropomorphic test devices (ATDs) during the testing. Results demonstrated that neither the human volunteers nor the ATDs experienced any significant motion relative to the vehicle's interior. If occupant motion were assumed to have occurred during the subject incident, the laws of physics and results from previous studies[19,20] dictate that [redacted] would have tended to move forward and rightward relative to the vehicle's interior. This motion would have been controlled and supported by the friction generated at her seat bottom, the center console, and the three point restraint. Specifically, the three-point restraint would have locked during the subject incident had the acceleration exceeded 0.7g and limited her forward body excursion.[21] Provided the low accelerations of the subject incident, and the supports described, the bodily response of [redacted] would have been limited to well within normal physiological limits

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to [redacted] was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of

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16 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

17 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

18 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

19 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

20 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

21 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failures is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

[redacted] was diagnosed with a right shoulder sprain/strain and adhesive capsulitis, right knee sprain/strain and lateral patellar compression syndrome, and left hip pain. [redacted] was also diagnosed with a cervical, thoracic, lumbar, and lumbosacral sprain/strain.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

<u>Right Shoulder</u>

According to the medical records, [redacted] had surgery prior to the subject incident in 2013 to repair a right shoulder posterior labral tear. After the subject incident, an MRI performed February 12, 2015 reported no evidence of re-tearing of the surgical repaired region, and an intact rotator cuff.

There is no reason to assume that the claimed left shoulder biomechanical failures are causally related to the subject incident. Biomechanical failures to the shoulder occur when an event consists of both the appropriate biomechanical failure mechanism and the force magnitude to exceed the strength of these structures. The occurrence of frozen shoulder may be idiopathic, disease related or following trauma to the shoulder, although specifics are not exactly clear. It has been found to be most prevalent in adults ages 40 to 70 years old, and in particular affecting females.[24,25,26] Adhesive capsulitis can also occur from under-use.

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22 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

23 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

24 Mengiardi, B., Pfirmann, C.W.A.., et al. (2004). Frozen Shoulder: MR Arthrographic Findings. *Radiology*, 233:486-492.

25 Hand, G.C.R., Arthanasou, N.A., et al. (2007). The pathology of frozen shoulder. *The Journal of Bone & Joint Surgery*, 89-B:928-32.

26 Bunker, T.D., Anthony, P.P. (1994). The pathology of frozen shoulder. *The Journal of Bone & Joint Surgery*, 77-B:677-83.

Scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, little occupant motion would have occurred.[27,28] [redacted] indicated that her right hand and arm were resting on the armrest, and her shoulder contacted the center console. If occupant motion were assumed, [redacted] would have moved forward and rightward relative to the vehicle's interior.[29,30] This motion would have been supported and constrained by the three-point restraint, seat bottom friction, and center console of the subject Hyundai. The direction, force, and magnitude of the impact would not be sufficient to cause biomechanical failure. The low accelerations in the subject incident and the restraint provided by the seatback and interior components of the subject vehicle were such that any motion of [redacted] right shoulder would have been limited to well within the range of normal physiological limits.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[31,32,33,34] [redacted] indicated that she was capable of performing normal activities of daily living, including dressing, cleaning, and bathing. These activities would directly load [redacted] right shoulder joint to comparable or greater loads than the subject incident.

As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported right shoulder biomechanical failures of [redacted] cannot be made.

Left Hip

An MRI of [redacted] left hip performed February 10, 2015 was reportedly normal.

The hip joint is a ball and socket joint formed between the pelvis and the femur. The specific anatomy consists of a cup shaped cavity within the pelvis lined with articular cartilage, known as the acetabulum and the femoral head, which is also lined with articular cartilage. The joint is sealed by the labrum which is a soft fibrocartilaginous outer edge of the acetabulum.

27 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

28 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

29 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

30 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

31 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics*. *42*(12), 1840-1849.

32 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics*, *19*(6), 586-594.

33 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).

34 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics*, *40*(10), 2139-2149.

As a result of the subject incident, [redacted] would move forward and rightward relative to her vehicle. Any forward rebound would have been well-controlled by the available restraint system.[35,36] The lap belt would have distributed loads across her lower torso and pelvis, controlling any significant forward motion along with the seat bottom friction. As such, this motion would unload legs and hips. These actions do not create the biomechanical failure mechanisms required for a hip biomechanical failure in [redacted] hips. The loading and kinematics of [redacted]. [redacted] left hip were well within the limits of human tolerance and physiological motion.

[redacted] indicated she was capable of performing daily activities and strenuous daily activities without biomechanical failure, including jogging. Daily activities and occurrences such as walking, stumbling, single leg hopping, and jumping have been shown to have comparable and greater impact forces on the body.[37,38,39,40,41,42,43,44,45,46,47,48] These actions would apply direct and repetitive loads to [redacted] hips of comparable or greater magnitude than she was exposed to during the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the hips. Finally, the forces created by the incident were well within the limits of human tolerance for the hips and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of [redacted] a causal link between the subject incident and claimed left hip biomechanical failures cannot be made.

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35 Saczalski, K., S. Syson, et al. (1993). Field Accident Evaluations and Experimental Study of Seat Back Performance Relative to Rear-Impact Occupant Protection (SAE 930346). Warrendale, PA, Society of Automotive Engineers.

36 Szabo, T. J., J. B. Welcher, et al. (1994). Human Occupant Kinematic Response to Low Speed Rear-End Impacts (SAE 940532). Warrendale, PA, Society of Automotive Engineers.

37 Keller, T.S., et al., (1996) "Relationship between vertical ground reaction force and speed during walking, slow jogging and running." *Clinical Biomechanics,* 11(5): 253-259.

38 Gottschall, J.S., Kram, R., (2005) "Ground reaction forces during downhill and uphill running." *Journal of Biomechanics,* 38: 445-452.

39 Bergmann, G., Graichen, F., Rohlmann, A., (2003) "Hip joint contact forces during stumbling." *Langenbecks Arch Surg,* 389:53-59.

40 Lindenberg, K.M., Garcia, C.R., (2013) "The influence of heel height on vertical ground reaction force during landing tasks in recreationally active and athletic collegiate females." *The International Journal of Sports Physical Therapy,* 8(1): 1-8.

41 Veilleux, L.N., Rauch, F., Lemay, M., Ballaz, L., (2012) "Agreement between vertical ground reaction force and ground reaction force vector in five common clinical tests." *J Musculoskeletal Neuronal Interact,* 12(4):219-223.

42 Kluitenberg, B., et al., (2012) "Comparison of vertical ground reaction forces during overground and treadmill running. A validation study." *BMC Musculoskeletal Disorders,* 1-8.

43 Schipplein, O.D, Andriacchi, T.P. (1991) "Interaction Between Active and Passive Knee Stabilizers During Level Walking." *Journal of Orthopaedic Research* 9: 113-119.

44 Nordin M. and Frankel V.H. (1989).Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

45 Taylor, W.R., Heller, M.O. et al. (2004). "Tibio-Femoral Loading During Human Gait and Stair Climbing." *Journal of Orthopaedic Research* 22: 625-632.

46 Devita, P. and Hortobagyi, T. (2003). "Obesity is Not Associated with Increased Knee Joint Torque and Power During Level Walking." *Journal of Biomechanics* 36: 1355-1362.

47 Gushue, D.L., Houck, J., Lerner, A.L. (2005). "Effects of Childhood Obesity on Three-Dimensional Knee Joint Biomechanics During Walking." *Journal of Pediatric Orthopedics* 25(6): 763-768.

48 Kaufman, K.R., Hughes, C., et al. (2001). "Gait Characteristics of Patients with Knee Osteoarthritis." *Journal of Biomechanics* 34: 907-915.

Right Knee

The available records indicate [redacted] had been diagnosed with patellar compression syndrome of her right knee in 2013, prior to the subject incident. An MRI dated February 12, 2015 was compared to an earlier MRI from 2013 and reported no fracture, osseous contusion, meniscal or ligamentous pathology. The report did show a focal moderate to high grade chondral fissuring on the medial femoral condyle. On April 16, 2015, an operative report indicated [redacted] underwent an arthropic synovectomy and lateral release to address her lateral patellar compression syndrome.

The patella is a sesamoid bone responsible for directing muscle forces from the quadriceps across the knee, generating a compressive force between the patella and the femur. Lateral patellar compression syndrome develops from a decreased contact area between the patellar and femoral articulating surfaces, creating increased localized loads to the lateral aspects of the respective bones.[49] The development of this syndrome arises from alterations in the bone from chronic stress patterns.

As a result of the subject incident, [redacted] would move forward and rightward relative to her vehicle, with her forward motion being well-controlled by the available restraint system. [redacted] indicated that her right knee contacted the center console, and possibly the dash. The lap belt would have limited any significant motion of her lower torso and pelvis, and thus her lower limbs. As such, this would also limit any significant forward motion of [redacted] right knee. Given the low acceleration associated with this incident, any lateral contact between [redacted] right knee and the center console would also be low. These actions do not create the biomechanical failure mechanisms required for a knee biomechanical failure. The loading and kinematics of [redacted] right knee was well within the limits of human tolerance and physiological motion.

The available documents indicate [redacted] was capable of performing daily activities prior to the subject incident, as well as walking and jogging. Daily activities and occurrences such as walking, stumbling, single leg hopping and jumping have been shown to have comparable and

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49 Biedert, R.M., and Sanchis-Alfonso, V., (2002). *Sources of anterior knee pain*. Clinics in Sports Medicine 21:335-347.

greater impact forces on the body. [50,51,52,53,54,55,56,57,58,59,60,61] These actions would apply direct and repetitive loads to [redacted] knees of comparable or greater magnitude than she was exposed to during the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the knees. Finally, the forces created by the incident were well within the limits of human tolerance for the knees and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of [redacted], a causal link between the subject incident and claimed right knee biomechanical failures cannot be made.

Cervical/Thoracic/Lumbar/Sacral Spine, and Sacroiliac Joint

A lumbar MRI performed on March 6, 2015 reported mild disc bulging at the L3-4, 4-5, and 5-S1 levels. Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute biomechanical failure or aggravation of a pre-existing intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[62] In the absence of this acute biomechanical failure mechanism for intervertebral disc failure, scientific investigations have shown that the above

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50 Keller, T.S., et al., (1996) "Relationship between vertical ground reaction force and speed during walking, slow jogging and running." *Clinical Biomechanics,* 11(5): 253-259.

51 Gottschall, J.S., Kram, R., (2005) "Ground reaction forces during downhill and uphill running." *Journal of Biomechanics,* 38: 445-452.

52 Bergmann, G., Graichen, F., Rohlmann, A., (2003) "Hip joint contact forces during stumbling." *Langenbecks Arch Surg,* 389:53-59.

53 Lindenberg, K.M., Garcia, C.R., (2013) "The influence of heel height on vertical ground reaction force during landing tasks in recreationally active and athletic collegiate females." *The International Journal of Sports Physical Therapy,* 8(1): 1-8.

54 Veilleux, L.N., Rauch, F., Lemay, M., Ballaz, L., (2012) "Agreement between vertical ground reaction force and ground reaction force vector in five common clinical tests." *J Musculoskeletal Neuronal Interact,* 12(4):219-223.

55 Kluitenberg, B., et al., (2012) "Comparison of vertical ground reaction forces during overground and treadmill running. A validation study." *BMC Musculoskeletal Disorders,* 1-8.

56 Schipplein, O.D, Andriacchi, T.P. (1991) "Interaction Between Active and Passive Knee Stabilizers During Level Walking." *Journal of Orthopaedic Research* 9: 113-119.

57 Nordin M. and Frankel V.H. (1989).Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

58 Taylor, W.R., Heller, M.O. et al. (2004). "Tibio-Femoral Loading During Human Gait and Stair Climbing." *Journal of Orthopaedic Research* 22: 625-632.

59 Devita, P. and Hortobagyi, T. (2003). "Obesity is Not Associated with Increased Knee Joint Torque and Power During Level Walking." *Journal of Biomechanics* 36: 1355-1362.

60 Gushue, D.L., Houck, J., Lerner, A.L. (2005). "Effects of Childhood Obesity on Three-Dimensional Knee Joint Biomechanics During Walking." *Journal of Pediatric Orthopedics* 25(6): 763-768.

61 Kaufman, K.R., Hughes, C., et al. (2001). "Gait Characteristics of Patients with Knee Osteoarthritis." *Journal of Biomechanics* 34: 907-915.

62 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

ARCCA

cervical disc diagnoses can be the result of the normal aging process.[63,64]

As described previously, the sideswipe event would have caused the subject Hyundai Veloster to decelerate longitudinally and accelerate leftward. Scientific literature in conjunction with experimentation conducted at ARCCA, indicates that provided the low accelerations of the event, little occupant motion would have occurred.[65,66] If occupant motion were assumed, [redacted] would have moved forward and rightward relative to the vehicle's interior.[67,68] This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Hyundai. [redacted] cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[69] As a result, [redacted] cervical spine motion would have been maintained to within normal physiological limits during the subject incident.[70] As described previously, [redacted] testified she was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited her forward body excursion.[71] The seat belt would have primarily engaged [redacted] bony left clavicle and pelvis distributing the load over her entire torso and limiting her motion. Therefore, [redacted] thoracic, lumbar, and sacral spine motion would have been limited to only minimal flexion and/or lateral bending during the subject incident. As a result, the motion of [redacted] thoracic, lumbar, and sacral spine during the subject incident would have been limited to within normal physiologic limits.

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63 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

64 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

65 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

66 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

67 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

68 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

69 Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

70 Mertz, H.J. Jr. and Patrick, L.M., (1967) Investigation of the Kinematics and Kinetics of Whiplash, (SAE 670919). Warrendale, PA: Society of Automotive Engineers.

71 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

Many research studies support these above conclusions. Human volunteers have been exposed to frontal and lateral impact accelerations at levels comparable to, and greater than that of the subject incident.[72,73,74,75,76,77,78,79,80,81,82] Participants moved toward the point of impact while their response was controlled by the three-point restraint, seat structures, and vehicle interior components. None of the volunteers reported cervical, thoracic, lumbar, or sacral trauma in response to this testing. Further research has exposed cadavers to impact accelerations within the biomechanical failure range.[83,84] These results demonstrated that the accelerations during the subject incident were maintained well within human tolerance as none of the cadaveric testing resulted in cervical trauma at acceleration levels consistent with the subject incident. The accelerations during the subject incident were maintained within published guidelines for safe human exposure to frontal and lateral impact accelerations.[85] In addition, these studies demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[86,87] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Research by Funk et al.[88] demonstrated that a simple head shake or a self-inflicted hand strike to the head induces accelerations comparable to or greater than the subject incident. In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces

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72 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

73 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

74 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

75 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

76 Matsushita, T., Sato, T.B., Hirabayashi, K., et al. (1994). X-ray Study of the Human Neck Motion Due to Head Inertia Loading (SAE 942208). Warrendale, PA. Society of Automotive Engineers.

77 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

78 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

79 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

80 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

81 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

82 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

83 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

84 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

85 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

86 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

87 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

88 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[89] Studies by Rohlmann et al.[90,91,92] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident. [redacted] performed daily activities without biomechanical failure prior to the subject incident. These activities would have generated cervical forces that were comparable to and greater than those of the subject incident.[93,94,95] These data demonstrate that the cervical forces of the subject incident did not exceed [redacted] personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical, thoracic, lumbar, and sacral spine biomechanical failures of [redacted] cannot be made.

Personal Tolerance Values

As noted previously, [redacted] was capable of performing common activities of daily living, such as vacuuming, bathing, laundry, walking, jogging, and dressing. Daily activities can produce greater movement, or stretch, to the soft tissues of [redacted] and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[96]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between [redacted] reported biomechanical failures and the

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89 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine,* 29(20):2319-2329.

90 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

91 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

92 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

93 Vijayakumar, V., Scher, I., Gloeckner, D.C., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA. Society of Automotive Engineers.

94 Choi, H., and Vanderby, R. (2000). "Muscle Forces and Spinal Loads at C4/5 Level During Isometric Voluntary Efforts." Medicine & Science in Sports & Exercise 830-838.

95 Moroney, S.P., Schultz, A.B., and Miller, J.A.A. (1988). "Analysis and Measurement of Neck Loads." Journal of Orthopaedic Research 6: 713-720.

96 Rudny, D.F., Sallmann, D.W. (1996) Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes). SAE Technical Paper Series #960654.

subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of [redacted] using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 25, 2014, [redacted] was the seat-belted driver of a 2013 Hyundai Veloster when contact occurred between its passenger's side and the left side of a 1997 Toyota Camry, resulting in a sideswipe collision.
2. The severity of the subject incident was consistent with a Delta-V less than 5.3 miles-per-hour with peak acceleration less than 2.5g for the subject 2013 Hyundai Veloster in which [redacted] was seated.
3. The acceleration experienced by [redacted] was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. Had the forces of the subject incident been sufficient to overcome the muscle reaction forces, [redacted] body would have moved forward and rightward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat bottom friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed right shoulder biomechanical failures. As such, a causal relationship between the subject incident and the right shoulder biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed left hip biomechanical failures. As such, a causal relationship between the subject incident and the left hip biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed right knee biomechanical failures. As such, a causal relationship between the subject incident and the right knee biomechanical failures cannot be made.
8. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed cervical, thoracic, lumbar, sacral, and sacroiliac biomechanical failures. As such, a causal relationship between the subject incident and the cervical, thoracic, lumbar, sacral, and sacroiliac biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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June 10, 2016

Stacy DeMass, Esquire
Law Offices of Sweeney, Heit & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Mekhael, Refaat and Ledia v. Heather Glynn*
Claim No.: 465382645036
ARCCA Case No.: 3271-356

Dear Ms. DeMass:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Ledia Mekhael. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the available documents, on November 27, 2013, Mr. Refaat Mekhael was the seat-belted driver of a 1994 Oldsmobile Eighty Eight stopped in the left turn lane on westbound Coal Creek Parkway Southeast in Bellevue, Washington. Ms. Ledia Mekhael was the seat-belted front passenger in the subject Oldsmobile. Ms. Heather Glynn was the driver of a 2006 BMW 325i immediately behind the subject Oldsmobile. According to the State of Washington Police Traffic Collision Report, while the subject Oldsmobile was stopped, contact was made between the front of the incident BMW and the rear of the Oldsmobile. No airbags were deployed and neither vehicle was towed from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. E288912* [November 27, 2013]
- Fifteen (15) color photographic reproductions of the subject 1994 Oldsmobile Eighty Eight
- Twelve (12) color photographic reproductions of the incident 2006 BMW 325i
- Deposition Transcript of Refaat Mekhael, *Ledia Mekhael and Refaat Mekhael vs. Heather Glynn and John/Jane Doe Glynn* [December 11, 2015]
- Deposition Transcript of Ledia Mekhael¸ *Ledia Mekhael and Refaat Mekhael vs. Heather Glynn and John/Jane Doe Glynn* [December 11, 2015]
- Demands Letter for Ledia Mekhael [October 2, 2014]
- Safeco Insurance Company of Illinois Estimate of Record for the subject 1994 Oldsmobile Eighty Eight [December 6, 2013]
- Medical Records pertaining to Ledia Mekhael
- VinLink data sheet for the subject 1994 Oldsmobile Eighty Eight
- Expert AutoStats data sheets for a 1994 Oldsmobile Eighty Eight
- VinLink data sheet for the incident 2006 BMW 325i
- Expert AutoStats data sheets for a 2006 BMW 325i
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Mekhael claims were caused by the subject incident on November 27, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1994 Oldsmobile Eighty Eight;
3. Determine Ms. Mekhael's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Mekhael's personal tolerance in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Mekhael attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - Disc degeneration
- Lumbar Spine
  - Sprain/strain
- Left Shoulder
  - Pain consistent with soft-tissue biomechanical failure

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair estimates of the subject 1994 Oldsmobile Eighty Eight and photographic reproductions of the incident 2006 BMW 325i in association with accepted scientific methodologies. [11,12]

The Estimate of Repair for the subject 1994 Oldsmobile Eighty Eight reported damage to the left tail lamp assembly. The photographs for the subject 1994 Oldsmobile Eighty Eight showed no residual crush to the rear of the vehicle, however, there was evidence that one of the rear bumper isolators had stroked. There were some scratches to the left corner of the rear bumper below the trim, and a small crack to the lower corner of the left tail light. The trim around the rear bumper cover was sticking out in various places. The rear bumper cover was in proper alignment with the quarter panels, tail lights, and trunk lid. Ms. Mekhael's testimony indicated that the damages to the subject Oldsmobile were minimal, stating, *"wasn't that damaged that much"*.

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[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

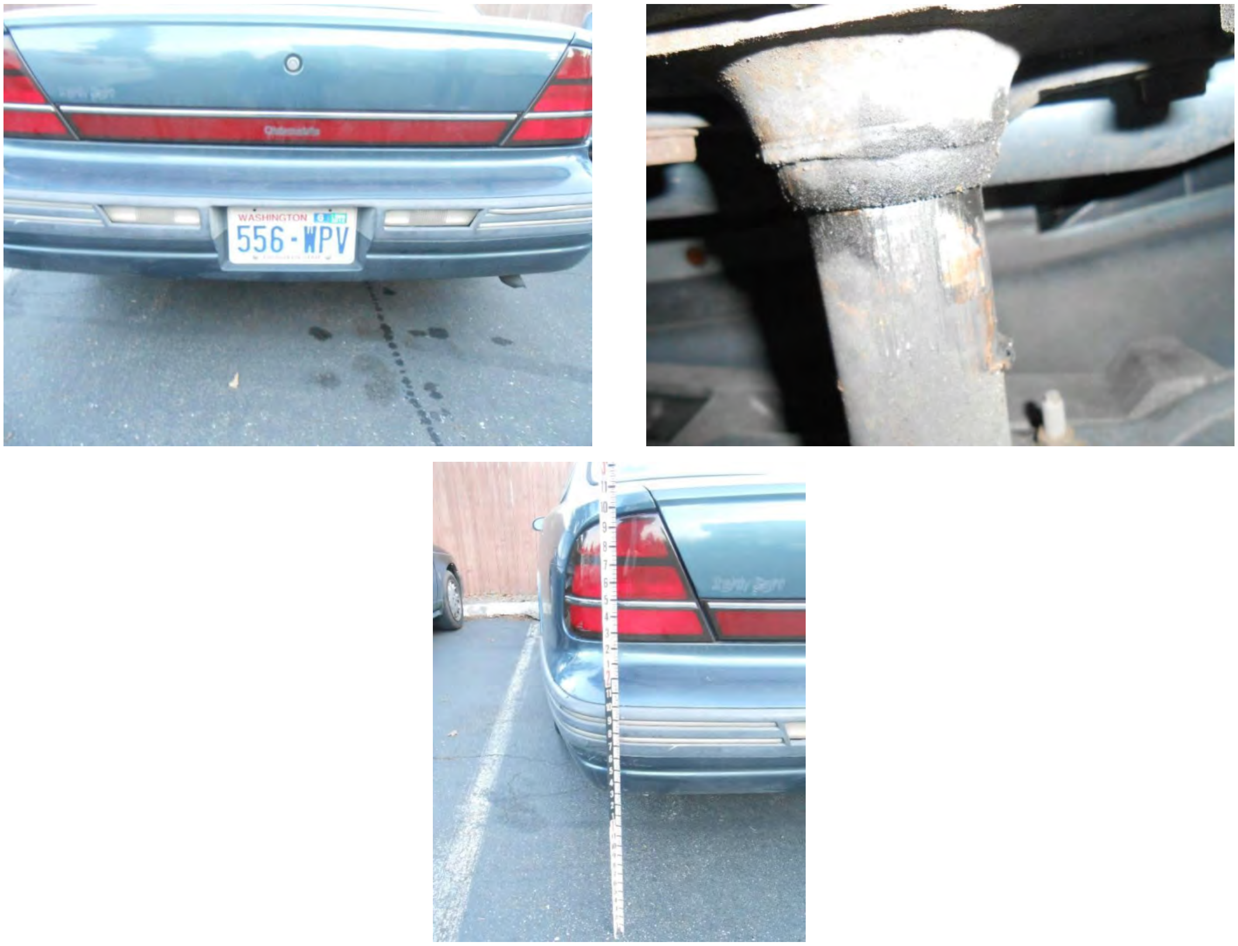

Figure 1: Reproductions of photographs of the subject 1994 Oldsmobile Eighty Eight

The photographs for the incident 2006 BMW 325i depicted no residual crush or signs of structural damage (Figure 2). The front bumper was well aligned with the head lights, grille, hood, and front fenders. There were minor chips and paint scratches to the right side of the front bumper cover.

Figure 2: Reproductions of photographs of the incident 2006 BMW 325i

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident BMW 325i can be used to resolve the loads sustained by the subject Oldsmobile Eighty Eight. That is, the loads sustained by the incident 325i are equal and opposite to those of the subject Eighty Eight. Furthermore, energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17]

Analyses of the photograph and geometric measurements of the incident 2006 BMW 325i revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the front of a BMW 325i of the same production year would result in significant and visibly noticeable crush across the entirety of the incident BMW's front structure, with a residual crush of 2.75 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 PC-Crash Collision Software.

vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20] The lack of significant structural crush to the entire front of the incident BMW along with the conservation of momentum indicates that the subject incident is consistent with a collision resulting in a Delta-V below 8.9 miles per hour for the subject Oldsmobile Eighty Eight. Additionally, the above analysis is consistent with an energy crush analysis to the rear of the subject Oldsmobile Eighty Eight.

Furthermore, the rear bumper of the subject Oldsmobile was equipped with two bumper shock isolators (also called hydraulic energy absorbers). The shock isolator acts as a shock, or impact absorber, between the bumper face bar and the structure of the vehicle. Compression testing of rear-bumper shock isolators was performed on a 1995 Oldsmobile Eighty Eight, essentially the same vehicle as the 1994 Oldsmobile Eighty Eight. The bumper isolator is an energy absorbing device and is designed to compress and allow for displacement of the bumper relative to the vehicle. After the load is removed, the bumper should return to its original position if the limit of the isolator was not exceeded. However, if the isolator is stroked beyond its maximum displacement, any additional force would be applied to deforming the structure of the vehicle. Newton's Second Law, which states that force is equivalent to the product of mass and acceleration, can be used to determine the maximum acceleration of the subject Oldsmobile. Testing indicated that at maximum stroke, for both isolators, the acceleration of the incident vehicle would be a maximum of 1.0g, based upon the published weight of the subject Oldsmobile.[21,22,23,24] The resulting delta-V is 2.3 miles-per-hour. By the laws of physics, the peak acceleration experienced by the subject Oldsmobile in which Ms. Mekhael was seated was significantly less than 1.0g.

The acceleration experienced due to gravity is 1g. This means that Ms. Mekhael experiences 1g of loading while in a sedentary state. Therefore, Ms. Mekhael experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[25] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

<u>Kinematic Analysis:</u>

Ms. Mekhael's medical records indicated she was 65.5 inches in height, weighed approximately 220 lbs., and was 44 years old at the time of the subject incident. Ms. Mekhael testified that the subject vehicle was stopped at the time of the subject incident. She further testified that the seat belt locked

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20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

21 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

22 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

23 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

24 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

25 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

during the incident (*"I felt the pressure"*), and her glasses fell off of her face. The records also indicated that her head was thrown back.

The laws of physics dictate that when the subject Oldsmobile Eighty Eight was contacted in the rear, it would have been pushed forward causing Ms. Mekhael's seat to move forward relative to her body. This motion would result in Ms. Mekhael moving rearward relative to the interior of the Oldsmobile Eighty Eight and loading into the seatback structures. Ms. Mekhael's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Mekhael was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Mekhael's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Mekhael would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the Oldsmobile Eighty Eight and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Mekhael was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[26,27]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc biomechanical failure involves a combination of hyperflexion or hyperextension and lateral bending with an

26 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

27 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

application of a sudden compressive load.[28] In the absence of this acute biomechanical failure mechanism for cervical or lumbar disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[29,30]

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

Ms. Mekhael attributed a cervical sprain/strain and disc degeneration to the subject incident. A cervical X-ray performed November 27, 2013 reported no abnormality.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Oldsmobile Eighty Eight would be pushed forward and Ms. Mekhael would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 1994 Oldsmobile Eighty Eight revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 26.0 inches in the full down position, and 29.25 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Mekhael revealed she would have a normal seated height of 33.4 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Mekhael's cervical spine would have undergone only a subtle degree of the characteristic response phases.[31] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[32] The cervical loads were within physiologic limits and Ms. Mekhael would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[33,34,35]

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28 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

29 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

30 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

31 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

32 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

33 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

34 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

35 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[36,37,38,39,40] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[41] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [42,43,44,45] The available documents reported Ms. Mekhael was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[46]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Mekhael cannot be made.

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36 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

37 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

38 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

39 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

40 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

41 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

42 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

43 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

44 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

45 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

46 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Lumbar Spine

The available documents indicate that Ms. Mekhael attributes a lumbar sprain/strain to the subject incident. A lumbar X-ray performed November 27, 2013 reported no abnormality, but noted lower lumbar degenerative changes.

During an event such as the subject incident, the lumbar spine of Ms. Mekhael is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Mekhael's lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the lumbar spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[47,48,49,50] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[51] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[52,53] Ms. Mekhael's lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[54,55,56,57,58]

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47 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

48 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

49 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

50 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

51 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

52 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

53 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

54 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

55 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

56 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

57 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

58 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [59,60,61,62] Further, studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[63,64] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[65] According to the available documents, Ms. Mekhael was capable of performing daily activities. A segmental analysis of Ms. Mekhael demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[66,67,68]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Mekhael, a causal link between the subject incident and claimed thoracic biomechanical failures cannot be made.

Left Shoulder

According to the medical records Ms. Mekhael attributes left shoulder pain consistent with soft tissue biomechanical failure to the subject incident.

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The primary mechanisms to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive

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59 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

60 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

61 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

62 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

63 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

64 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

65 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

66 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

67 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

68 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

microtrauma to the abducted shoulder joint.[69,70,71] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder.

During the subject incident, Ms. Mekhael's body and extremities would have moved rearward relative to the subject vehicle's interior.[72,73,74,75] This rearward motion would have been supported by the seatback. Ms. Mekhael's upper torso would have loaded into the seat structures and if there was rebound, the seat belt would have engaged Ms. Mekhael's bony right clavicle had the accelerations exceeded 0.7g.[76] As noted previously, Ms. Mekhael testified that she *"felt the pressure"* of the seat belt during the subject incident. This interaction with the seat back and seat belt would have limited her motion during the subject incident.

Many studies have shown that shoulder forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[77,78,79,80] Ms. Mekhael testified she was capable of performing normal and strenuous daily activities without biomechanical failure. These activities would directly load Ms. Mekhael's shoulders to comparable or greater loads than the subject incident.

The low accelerations in the subject incident and the restraint provided by the seatback, were such that any motion of Ms. Mekhael's left shoulder would have been limited to well within the range of normal physiological limits. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported left shoulder biomechanical failures of Ms. Mekhael cannot be made.

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69 Moore, K.L. and Dalley, A.F. (1999). Clinically Oriented Anatomy, Fourth Edition, Lippencott Williams and Wilkins.

70 Melenevsky, Y., Yablon, C.M., Ramappa, A., Hochman, M.G. (2009) "Clavicle and Acromioclavicular Joint Injuries: A Review of Imaging, Treatment, and Complications." Skeletal Radiology. 40:831-842.

71 Simovitch, R., Sanders, B., Ozbaydar, M., Lavery, K., Warner, J.J.P., (2009) "Acromioclavicular Joint Injuries: Diagnosis and Management." J Am Acad Orthop Surg. 4:207-219.

72 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

73 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.

74 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

75 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions.* (No. 2010-01-0067). SAE Technical Paper.

76 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

77 Westerhoff, P., Graichen, F., Bender, A., Halder, A., Beier, A., Rohlmann, A., & Bergmann, G. (2009). In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living. *Journal of Biomechanics*. *42*(12), 1840-1849.

78 Murray, I.A., & Johnson, G.R. (2004). A study of the external forces and moments at the shoulder and elbow while performing every day tasks. *Clinical Biomechanics*, *19*(6), 586-594.

79 Anglin, C., Wyss, U.P., & Pichora, D.R. (1997). Glenohumeral contact forces during five activities of daily living. In *First Conference of the International Shoulder Group* (pp. 13-8).

80 Bergmann, G., Graichen, F., Bender, A., Kääb, M., Rohlmann, A., & Westerhoff, P. (2007). In vivo glenohumeral contact forces—measurements in the first patient 7 months postoperatively. *Journal of Biomechanics*, *40*(10), 2139-2149.

Personal Tolerance Values

According to the available documents, Ms. Mekhael was capable of performing normal activities of daily living without biomechanical failure. She testified that she was a teacher at a day care, specifically working with infants, and was required to lift and carry them regularly. Further, common activities can produce greater movement, or stretch, to the soft tissues of Ms. Mekhael and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[81]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Mekhael's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Mekhael using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 27, 2013, Ms. Ledia Mekhael was the seat-belted front passenger of a 1994 Oldsmobile Eighty Eight that was stopped on Coal Creek Parkway Southeast in Bellevue, Washington, when low speed contact occurred between the rear of the subject Oldsmobile Eighty Eight and the front of a 2006 BMW 325i.
2. The severity of the subject incident had a peak acceleration less than 1.0g with a delta-V of 2.3 miles-per-hour.
3. The acceleration experienced by Ms. Mekhael was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the Oldsmobile Eighty Eight during the subject incident would tend to move Ms. Mekhael's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mekhael's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mekhael's claimed lumbar biomechanical failures. As such, a causal relationship between the subject incident and the lumbar biomechanical failures cannot be made.

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81 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mekhael's claimed left shoulder biomechanical failures. As such, a causal relationship between the subject incident and the left shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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June 14, 2016

Branden Reist
Liberty Mutual Insurance Company
P. O. Box 7230
London, KY 40742

Re: *Olson, Jessica v. Pamela Duff*
Claim No.: 028207334
ARCCA Case No.: 2107-1042

Dear Mr. Reist:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Jessica Olson. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on October 23, 2013, Ms. Jessica Olson was the seat-belted driver of a 1996 Toyota Corolla. Ms. Pamela Duff was the driver of a 2007 Toyota FJ Cruiser traveling immediately behind the subject Toyota Corolla. While stopped at a traffic signal, contact was made between the rear of the subject Corolla and the front of the incident FJ Cruiser.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Seven (7) color photographic reproductions of the subject 1996 Toyota Corolla
- Complete Collision Center Corp. Supplement 2 for repairs of the subject 1996 Toyota Corolla [December 11, 2013]
- Medical Records pertaining to Jessica Olson
- VinLink data sheet for the subject 1996 Toyota Corolla
- Expert AutoStats data sheets for a 1996 Toyota Corolla
- VinLink data sheet for the incident 2007 Toyota FJ Cruiser
- Expert AutoStats data sheets for a 2007 Toyota FJ Cruiser
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Olson claims were caused by the subject incident on October 23, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1996 Toyota Corolla;
3. Determine Ms. Olson's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

5. Evaluate Ms. Olson's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Olson attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic Spine
    - Sprain/strain
- Lumbar Spine
    - Sprain/strain
    - L3-4 posterior lateral disc bulge and tear
    - L4-5 posterior annulus disc bulge and tear
    - L5-S1 concentric disc bulge and tear

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 1996 Toyota Corolla in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject 1996 Toyota Corolla reported damage to the rear bumper cover, left and right bumper mounting brackets, and rear body panel, which is consistent with the reviewed photographs (Figure 1). The photographs depicted no residual crush to the rear bumper cover. There was no damage to the exhaust pipe, tail lights, or lift gate, and the license plate did not appear distorted.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 1996 Toyota Corolla

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements, along with the repair record of the subject 1996 Toyota Corolla revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the rear of a 1996 Toyota Corolla would result in significant and visibly noticeable crush across the entirety of the subject Corolla's rear structure, with a residual crush of 4.75 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20] The lack of significant structural crush to the entire front of the subject Toyota Corolla indicates a collision resulting in a Delta-V significantly below 10 miles per hour.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 PC-Crash Collision Software.

20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

Further, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident 1996 Toyota Corolla, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[21] The IIHS tested an exemplar Toyota Corolla in a 5 mile-per-hour rear impact into a full width rigid barrier.[22] The test Toyota Corolla sustained damage to the rear bumper cover, bumper reinforcement, left and right bumper mounting brackets, and left and right license lamp housings. The primary damage to the subject Toyota Corolla was to the rear bumper cover, left and right mounting brackets, and rear body panel. Thus, because the test Toyota Corolla in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is consistent with the severity of the subject incident, and results in a Delta-V of 6.5 miles-per-hour.[23,24]

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour Delta-V is 3.0g, and the average acceleration associated with a 6.5 mile-per-hour Delta-V is 2.0g.[25,26,27,28] By the laws of physics, the average acceleration experienced by the subject Toyota Corolla in which Ms. Olson was seated was significantly less than 3.0g and more consistent with 2.0g.

The acceleration experienced due to gravity is 1g. This means that Ms. Olson experiences 1g of loading while in a sedentary state. Therefore, Ms. Olson experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [29] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Olson's medical records indicated she was 64 inches in height, weighed approximately 173 lbs., and was 31 years old at the time of the subject incident. The records indicate Ms. Olson was belted, facing forward, and had both hands on the steering wheel. She also indicated that her foot was on the brake, and she was aware of the oncoming impact.

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21 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

22 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 1998 Toyota Corolla, November 1997.

23 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

24 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

25 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

26 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

27 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

28 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

29 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

The laws of physics dictate that when the subject Toyota Corolla was contacted in the rear, it would have been pushed forward causing Ms. Olson's seat to move forward relative to her body. This motion would result in Ms. Olson moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Olson's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Olson was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Olson's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Olson would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Olson was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[30,31]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

According to the medical records, Ms. Olson attributes a cervical, thoracic, and lumbar sprain/strain to the subject incident. She also attributes lumbar disc bulging and tearing to the L3-4, L4-5, and L5-S1 levels.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc biomechanical failure involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[32] In the absence of this acute biomechanical failure

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[30] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
[31] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.
[32] White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

mechanism for lumbar disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[33,34]

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota Corolla would be pushed forward and Ms. Olson would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 1996 Toyota Corolla revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 28.25 inches in the full down position, and 31.5 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Olson revealed she would have a normal seated height of 32.8 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Olson's cervical spine would have undergone only a subtle degree of the characteristic response phases.[35] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[36] The cervical loads were within physiologic limits and Ms. Olson would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[37,38,39]

Several researchers have conducted human volunteer rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[40,41,42,43,44] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the

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33 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

34 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

35 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

36 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

37 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

38 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

39 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

40 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

41 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

42 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

43 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

44 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[45] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [46,47,48,49] The available documents reported Ms. Olson was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[50]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Olson cannot be made.

Thoracic and Lumbar Spine

A lumbar MRI performed March 21, 2015 reported disc degeneration at multiple levels, a broad-based disc bulge at L5-S1, and a mild broad-based disc bulge at L3-4 as well as L4-5. An additional MRI performed October 26, 2015 also reported disc degeneration greatest at L4-5 and L5-S1 (both with disc bulges), posterior tears at L4-5 and L5-S1, and a mild disc bulge at L3-4. On December 1, 2015 Ms. Olson underwent a lumbar discogram at the L2-3, L3-4, and L5-S1 levels.

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Olson is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Olson's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus, it would not be

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45 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

46 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

47 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

48 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

49 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

50 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[51,52,53,54] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[55] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[56,57] Ms. Olson's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[58,59,60,61,62]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [63,64,65,66] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or

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51 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

52 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

53 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

54 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

55 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

56 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

57 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

58 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

59 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

60 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

61 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

62 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

63 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

64 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

65 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

66 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

greater than the subject incident.[67,68] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[69] According to the available documents, Ms. Olson was capable of performing daily activities. A segmental analysis of Ms. Olson demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[70,71,72]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Olson, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Ms. Olson was employed as a hand finisher at Boeing. The records also indicate that she was capable of performing activities of daily living without biomechanical failure. Activities of daily living can produce greater movement, or stretch, to the soft tissues of Ms. Olson and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Olson's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Olson using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On October 23, 2013, Ms. Jessica Olson was the seat-belted driver of a 1996 Toyota Corolla that was stopped at a traffic signal, when the subject Toyota Corolla was contacted in the rear at low speed by a 2007 Toyota FJ Cruiser.

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67 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

68 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

69 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

70 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

71 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

72 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

2. The severity of the subject incident was significantly below 10 miles-per-hour with an average acceleration less than 3.0g, and more consistent with 6.5 miles-per-hour with an average acceleration of 2.0g.
3. The acceleration experienced by Ms. Olson was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Olson's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Olson's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Olson's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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September 28, 2017

Branden Reist
Liberty Mutual Insurance Company
P. O. Box 7230
London, KY 40742

Re: *Olson, Jessica v. Pamela Duff*
Claim No.: 028207334
ARCCA Case No.: 2107-1042

Dear Mr. Reist:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Jessica Olson. This letter serves as a supplement to my report of June 14, 2016. Since that time, I have had the opportunity to review and evaluate additional documents.

Additional Information Reviewed:

- Incident severity report by Allan Tencer, Ph.D. [September 15, 2017]

Discussion:

Dr. Tencer makes several opinions regarding the incident severity and occupant motion as a result from the subject incident. However, there are issues in these opinions that must be addressed.

In Dr. Tencer's first opinion, his evaluation of the incident severity is based entirely on the performance of the foam energy absorber of the rear bumper assembly. As identified within Dr. Tencer's report, a breakout diagram of the rear bumper assembly shows multiple additional components as part of the bumper assembly, such as the rear bumper cover and reinforcement bar. The collective rear bumper assembly is responsible for energy absorption during a rear-end impact. Analyzing the properties of a single entity of the rear bumper assembly system, and thus extrapolating that to apply to the entire assembly is inaccurate and misleading. Dr. Tencer has ignored any "weak links", or the weakest part of a system could result in failure. Dr. Tencer looked at one of the stronger, if not strongest, components.

In Dr. Tencer's second opinion, he refers to a video as evidence for the *"extent and violence of the movements"* of an occupant in a rear impact. This video lacks scientific merit and is anecdotal at best. First, the occupant in the driver's seat is clearly aware of an oncoming rear impact, a fact which Dr. Tencer's own research paper attempts to discourage (SAE Technical Paper 1999-01-0442, reference in his report). Second, there is no information regarding the parameters of the test being performed, such as the type of vehicle, occupant anthropometrics, impact specifications, repeatability, statistical relevance, etc. The lack of details about this video makes its exemplary nature moot, and is a frivolous representation of occupant motion during rear impacts. It is also misleading in that while attempting to characterize the "violence" of the impact, Dr. Tencer fails to link this evidence to the subject incident or provide any quantitative fact.

Dr. Tencer continues to address specific claims made in my initial June 14, 2016 report.

In Dr. Tencer's third opinion, he states that the IIHS barrier test referred to in my initial report was based entirely on a dollar amount of repairs. Dr. Tencer is mistaken, however, as he did not correctly read the reference provided in my report. I referenced a full low-speed crash test report performed November of 1997, and provided a full description of the damage and components damaged from the test (again, these components were listed within my initial report, but were missed by Dr. Tencer). The report Dr. Tencer refers to is a semi-monthly digest published by the IIHS that provides a small synopsis of the full test reports, such as the one used in my analysis. While Dr. Tencer's evaluation of the brief synopsis he accessed is accurate, they are completely wrong and not applicable to the full report that was referenced in my initial report.

Dr. Tencer continues to claim that I did not have the necessary information to evaluate Ms. Olson's personal tolerances. As noted in my initial report, I was provided medical records for Ms. Olson, as well as her specific anthropometrics and information on her daily activities. Please refer to the section of my initial report labeled *"Personal Tolerance Values"*.

Dr. Tencer objects that the strength and tolerance levels of Ms. Olson are unknowable. While true, Ms. Olson herself was not specifically tested, this is by no means feasible or necessary to evaluate personal tolerances. Numerous papers have examined human tolerances across various ages, genders, and demographics to determine statistically significant values of tolerance. Dr. Tencer is indicating that without specifically testing a specific individual, it is impossible to know anything about that individual. However, in Dr. Tencer's own research such as the SAE Technical Paper 1999-01-0442 reference in his report, no documentation is provided that any personal tolerance evaluation was performed prior to exposing the study participants to comparable forces in rear end collisions. Yet Dr. Tencer and his colleagues identified loads that were deemed safe for the study participants (or, Dr. Tencer knowingly exposed study participants to intentionally harmful events).

Again, numerous reports were cited in my initial report that refer to human tolerance values across various demographics, age, gender, and anthropometrics. These studies and their findings are used across disciplines, for example, in surgical intervention, physical therapy, safe equipment development, ergonomics, transportation safety, building standards, commercial product development, etc. If any knowledge of human tolerance for an individual was unknowable without actually evaluating said individual, then all of the previously mentioned fields and their advancements would effectively not exist as they do today.

In our severity analyses, the "benefit of doubt" is given to the claimant, such that the worst-case scenario is considered. The analyses in my initial report indicated an incident significantly less than 10 miles-per-hour and closer to 6.4 miles-per-hour. Dr. Tencer's evaluation, though flawed and incomplete, claims the incident was approximately 8 miles-per-hour. This value is in fact within the range I initially reported, and does not change my original conclusions.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This report is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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June 28, 2016

[redacted]

[redacted]

Dear [redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of [redacted]. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

ARCCA INCORPORATED

Incident Description:

According to the available documents, on September 19, 2013, [redacted] was the seat-belted driver of a 2009 Toyota Matrix traveling on George Washington Way in Richland, Washington. [redacted] was the driver of a 2008 Toyota Highlander traveling immediately behind the subject Toyota Matrix. While stopped in traffic, contact was made between the rear of the subject Matrix and the front of the incident Highlander. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) color photographic reproductions of the subject 2009 Toyota Matrix
- Twenty-one (21) color photographic reproductions of the incident 2008 Toyota Highlander
- Precision-Kennewick Estimate of Record for the subject 2009 Toyota Matrix [October 8, 2013]
- First National Insurance Company of America Estimate of Record for the incident 2008 Toyota Highlander [October 24, 2013]
- First National Insurance Company of America Unrelated Prior Damage for the incident 2008 Toyota Highlander [October 24, 2013]
- Deposition Transcript of [redacted] [December 1, 2015]
- Medical Records pertaining to [redacted]
- VinLink data sheet for the subject 2009 Toyota Matrix
- Expert AutoStats data sheets for a 2009 Toyota Matrix
- VinLink data sheet for the incident 2008 Toyota Highlander
- Expert AutoStats data sheets for a 2008 Toyota Highlander
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

1. Identify the biomechanical failures that [redacted] claims were caused by the subject incident on September 19, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2009 Toyota Matrix;
3. Determine [redacted] kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate [redacted] personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate [redacted] attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2009 Toyota Matrix and the incident 2008 Toyota Highlander in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject 2009 Toyota Matrix reported damage to the rear bumper spoiler and rear bumper cover, which is consistent with the reviewed photographs (Figure 1). The photographs depicted bolt marks to the right center of the lower bumper spoiler. The rear bumper cover was in proper alignment with the tail lights, quarter panels, and tail gate.

11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 2009 Toyota Matrix

The repair documents for the incident 2008 Toyota Highlander indicated there was no damage related to the subject incident. The repair documents did note prior damage to the left corner of the front bumper cover, and a crack to the center of the lower grille. The photographs depicted the crack to the lower grille, which was recessed from the front bumper cover (Figure 2). The front bumper cover was in alignment with the head lamps, upper grille, fenders, and hood.

Figure 2: Reproductions of photographs of the incident 2008 Toyota Highlander

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 2009 Toyota Matrix revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the rear of a 2009 Toyota Matrix would result in significant and visibly noticeable crush across the entirety of the subject Matrix's rear structure, with a residual crush of 3 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20]

Additionally, the above analysis is consistent with an energy crush analysis to the front of the incident 2008 Toyota Highlander.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour Delta-V is 3.0g.[21,22,23,24] By the laws of physics, the average acceleration experienced by the subject Toyota Matrix in which [redacted] was seated was significantly less than 3.0g.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.
14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.
15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.
16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.
17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.
18 EDCRASH, Engineering Dynamics Corp.
19 PC-Crash Collision Software.
20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.
21 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.
22 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.
23 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.
24 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

The acceleration experienced due to gravity is 1g. This means that [redacted] experiences 1g of loading while in a sedentary state. Therefore, [redacted] experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[25] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

[redacted] medical records indicated she was 67 inches in height, weighed approximately 157 lbs., and was 35 years old at the time of the subject incident. [redacted] testified that she was aware of the oncoming impact and was braced. She also testified her foot was on the brake, her hands were on the steering wheel, and she did not strike the interior of the subject Toyota.

The laws of physics dictate that when the subject Toyota Matrix was contacted in the rear, it would have been pushed forward causing [redacted] seat to move forward relative to her body. This motion would result in [redacted] moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. [redacted] torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated [redacted] was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled [redacted] body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of [redacted] would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to [redacted] was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[26,27]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

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25 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.
26 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
27 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

[redacted] attributed a cervical and thoracic sprain/strain to the subject incident. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Toyota Matrix would be pushed forward and [redacted] would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. The National Highway Traffic Safety Administration (NHTSA) performs impact safety tests for continued performance and safety monitoring of the automotive industry. Testing for a 2009 Toyota Matrix showed the seated height of a 50th percentile male in the driver's seat was well protected and supported by the seatback components (Figure 4). [28]

Figure 3: NTHSA 50th percentile male in 2009 Toyota Matrix

[redacted] medical records indicated she was 67 inches tall, approximately 157 lbs., and 35 years old at the time of the subject incident. Performing an anthropometric regression of [redacted] revealed she would have a normal seated height of 33.9 inches, approximately one inch shorter than a 50th percentile male. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that [redacted] cervical spine would have undergone only a subtle degree of the characteristic response phases.[29] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[30] The cervical

28 National Highway Traffic Safety Administration (2009). Vehicle Safety Compliance Testing for FMVSS 208/212/219/301, Report No. 208-MGA-2009-007. 2009 Toyota Matrix.

29 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

30 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

loads were within physiologic limits and [redacted] would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[31,32,33]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[34,35,36,37,38] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[39] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [40,41,42,43] The available documents reported [redacted] was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash

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31 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

32 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

33 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

34 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

35 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

36 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

37 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

39 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

40 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

41 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

42 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

43 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

44 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of [redacted] cannot be made.

Thoracic Spine

During an event such as the subject incident, the thoracic spine of [redacted] is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of [redacted] thoracic spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[45,46,47,48] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[49] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[50,51] [redacted] thoracic spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[52,53,54,55,56]

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45 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

46 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

47 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

48 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

49 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

50 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

51 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

52 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

53 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

54 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

55 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

56 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[57,58,59,60] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[61,62] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[63] According to the available documents, [redacted] was capable of performing daily activities. A segmental analysis of [redacted] demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[64,65,66]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of [redacted] a causal link between the subject incident and claimed thoracic biomechanical failures cannot be made.

<u>Personal Tolerance Values</u>

According to the available documents, [redacted] was employed as a program director and adjunct faculty for Washington State University. She testified that her normal routine included exercising, specifically running, riding a bicycle, and using an incline trainer. She also testified that she enjoyed camping, and was capable of performing her daily activities without biomechanical failure. These activities can produce greater movement, or stretch, to the soft tissues of [redacted] and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to

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57 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

58 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

59 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

60 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

61 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

62 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

63 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

64 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

65 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

66 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between [redacted] reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of [redacted] using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On September 19, 2013, [redacted] was the seat belted driver of a 2009 Toyota Matrix that was stopped on George Washington Way in Richland, Washington, when the subject Matrix was contacted in the rear at low speed by a 2008 Toyota Highlander.
2. The severity of the subject incident was significantly below 10 miles-per-hour with an average acceleration less than 3.0g.
3. The acceleration experienced by [redacted] was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move [redacted] body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed thoracic biomechanical failures. As such, a causal relationship between the subject incident and the thoracic biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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EXHIBIT
Probst 40
5-23-17 MT

August 10, 2016

Tiffany Hall-Johnson, Esquire
Law Offices of Sweeney & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *O'Brien, Joell v. Timothy Doherty*
Claim No.: 3610 7178 5002
ARCCA Case No.: 2107-1064

Dear Ms. Hall-Johnson:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Joell O'Brien. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

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Incident Description:

According to the available documents, on February 27, 2015, Ms. Joell O'Brien was the seat-belted driver of a 2013 Toyota Corolla merging on to South Meridian in Puyallup, Washington. Mr. Tim Doherty was the driver of a 2013 Toyota Prius traveling immediately behind the subject Corolla. While stopped for traffic, contact was made between the rear of the subject Toyota Corolla and the front of the incident Toyota Prius. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Ten (10) color photographic reproductions of the subject Toyota Corolla
- Ten (10) color photographic reproductions of the incident Toyota Prius
- Lakewood Auto Body Estimate of Record for the subject 2013 Toyota Corolla [March 16, 2015]
- Lakewood Auto Body Estimate of Record 1 with Summary for the subject 2013 Toyota Corolla [March 16, 2015]
- Lakewood Auto Body Estimate of Record 2 with Summary for the subject 2013 Toyota Corolla [May 22, 2015]
- Recorded Statement Transcript of Joell O'Brien
- Recorded Statement Transcript of Tim Doherty [April 9, 2015]
- Deposition Transcript of Tim Doherty, *Joell M. O'Brien vs. Timothy P. Doherty and "Jane Doe" Doherty* [June 30, 2016]
- Deposition Transcript of Joell M. O'Brien, *Joell M. O'Brien vs. Timothy P. Doherty and "Jane Doe" Doherty* [June 30, 2016]
- Medical Records pertaining to Joell O'Brien
- VinLink data sheet for the subject 2013 Toyota Corolla
- Expert AutoStats data sheets for a 2013 Toyota Corolla
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. O'Brien claims were caused by the subject incident on February 27, 2015;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2013 Toyota Corolla;
3. Determine Ms. O'Brien's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. O'Brien's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. O'Brien attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbosacral Spine
  - Sprain/strain
- Sacroiliac Joint
  - Sprain/strain

6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

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Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2013 Toyota Corolla and photographic reproductions of the incident 2013 Toyota Prius in association with accepted scientific methodologies. [11,12]

The repair estimate for the subject 2013 Toyota Corolla reported damage to the rear bumper cover, which is consistent with the reviewed photographs (Figure 1). The photographs depicted no significant residual crush to the rear bumper. There was a small paint scuff to the lower left portion of the bumper cover, indicating the point of impact. The rear bumper was also in general alignment with the tailgate, tail lamps, and quarter panels. In her testimony, Ms. O'Brien stated the damage was to the left corner of the rear bumper, noting the *"bumper was hanging off"* and that there were scratches. Mr. Doherty's testimony indicated he pushed the bumper back in to place.

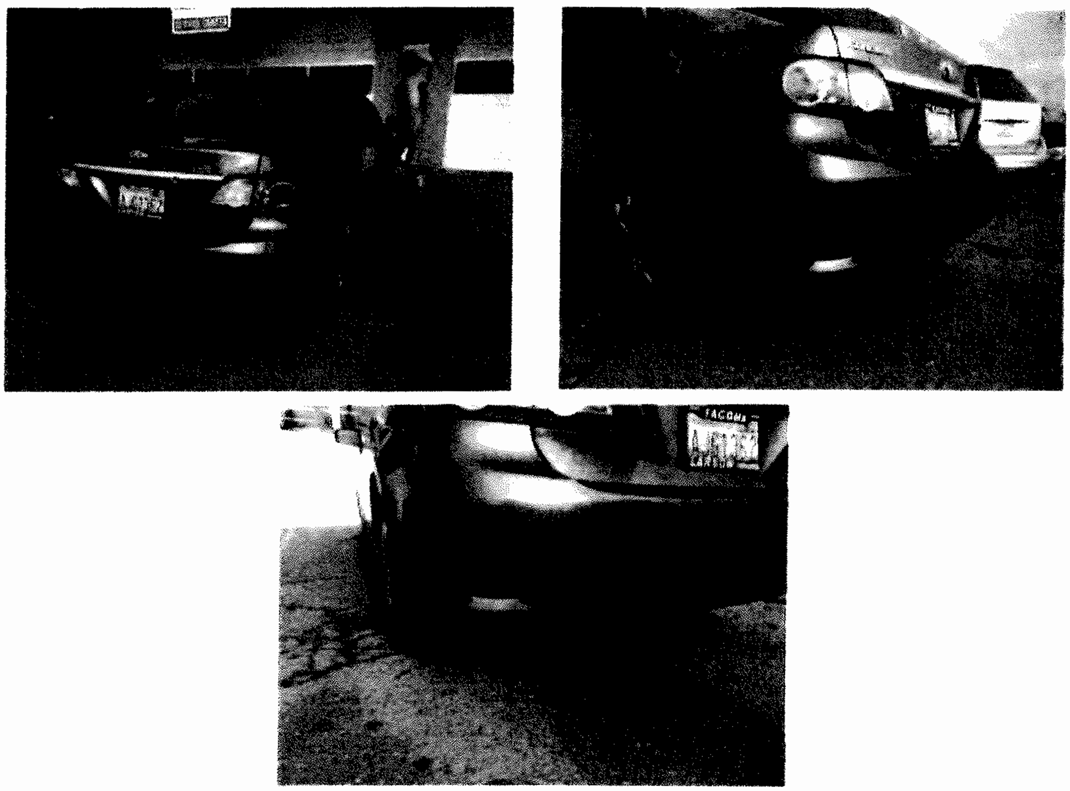

Figure 1: Reproductions of photographs of the subject 2013 Toyota Corolla

The photographic reproductions of the incident 2013 Toyota Prius depicted small chips to the lower edge of the front bumper, below the air guide (Figure 2). There was also a small dent to the upper corner of the license plate. There was no residual crush, and no apparent malalignment of the front bumper with respect to the grill, headlamps, hood, or fenders. Mr. Doherty testified there was no damage to the incident vehicle.

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

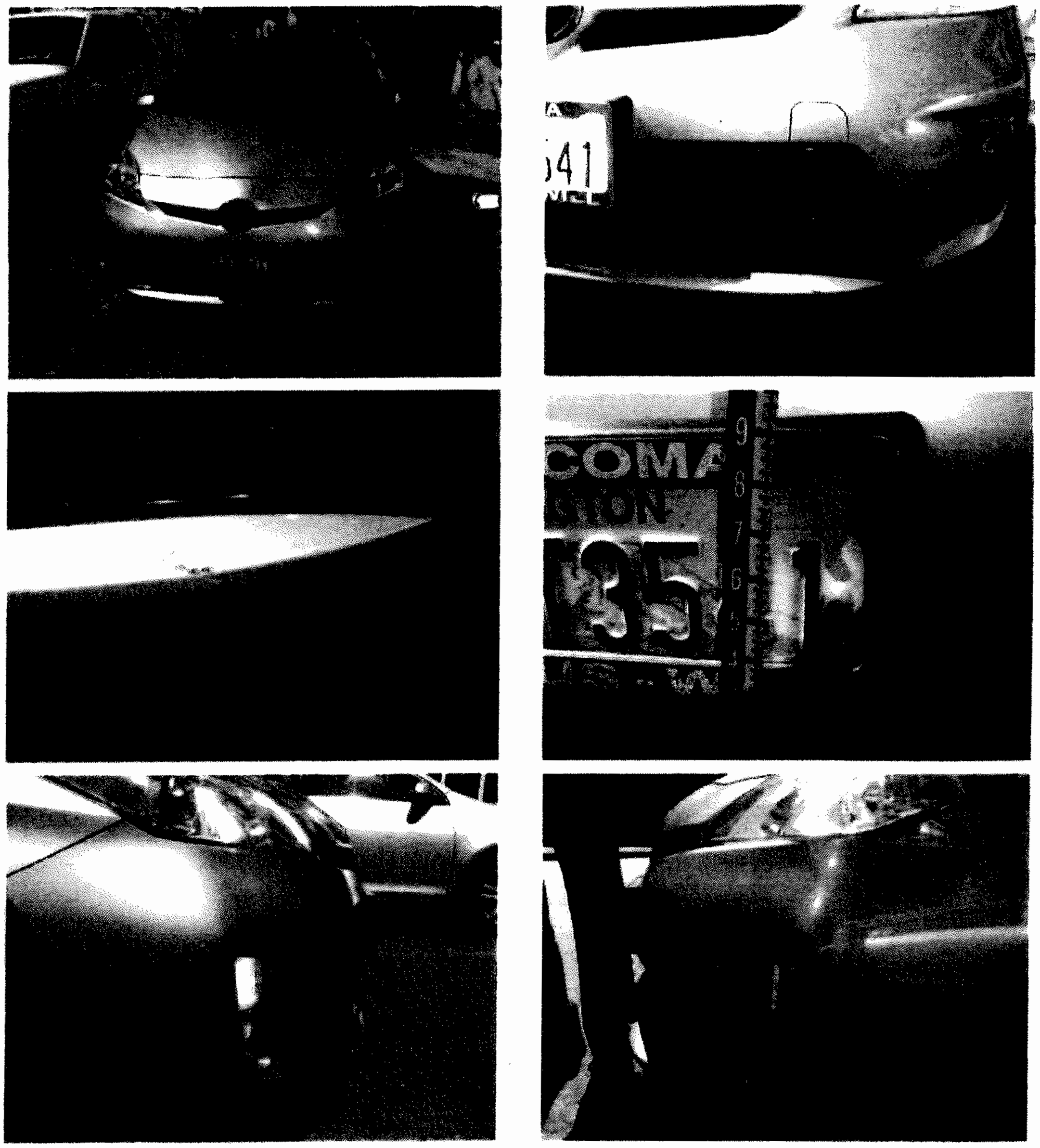

Figure 2: Reproductions of photographs of the incident 2013 Toyota Prius

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject 2013 Toyota Corolla, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested an exemplary 2013 Toyota Corolla in a 6.2 mile-per-hour rear impact into a flat barrier.[14] The test resulted in *"cover, energy absorber and reinforcement damage"*, as well as slightly bending the rear body panel. The

[13] Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

[14] Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2009-2012 Toyota Corolla.

primary damage to the subject Toyota Corolla was to the rear bumper cover. Thus, because the test Toyota Corolla in the IIHS rear impact test sustained significantly greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident. Accounting for restitution, the subject Toyota Corolla experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of 8.0 miles-per-hour or less.[15,16]

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with an 8.0 mile-per-hour Delta-V is 2.4g.[17,18,19,20] By the laws of physics, the average acceleration experienced by the subject Toyota Corolla in which Ms. O'Brien was seated was significantly less than 2.4g.

The acceleration experienced due to gravity is 1g. This means that Ms. O'Brien experiences 1g of loading while in a sedentary state. Therefore, Ms. O'Brien experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[21] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. O'Brien testified she was looking forward, her hands were on the steering wheel, and she was unaware of the oncoming impact. She further testified her foot was on the brake, and her *"head went forward and then went back and hit my headrest."*.

The laws of physics dictate that when the subject Toyota Corolla was contacted in the rear, it would have been pushed forward causing Ms. O'Brien's seat to move forward relative to her body. This motion would result in Ms. O'Brien moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. O'Brien's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. O'Brien was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. O'Brien's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. O'Brien would have been limited to well within the range of normal physiological limits.

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15 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

16 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

17 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration.* (No. 2000-01-0880). SAE Technical Paper.

18 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

19 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts.* (No. 970120). SAE Technical Paper.

20 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

21 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

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Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. O'Brien was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Subject Vehicle would be pushed forward and Ms. O'Brien would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2013 Toyota Corolla revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.0 inches in the full down position, and 34.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. O'Brien's cervical spine would have undergone only a subtle degree of the characteristic response phases.[24] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[25] The cervical loads were within physiologic limits and Ms.

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22 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

23 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck.* (No. 710855). SAE Technical Paper.

24 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

25 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

O'Brien would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[26,27,28]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[29,30,31,32,33] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[34] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [35,36,37,38] The available documents reported Ms. O'Brien was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[39]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash

26 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

27 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

28 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

29 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

30 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

31 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

32 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

33 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

34 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, 29(9), 979-987.

35 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

36 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

37 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

38 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

39 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. O'Brien cannot be made.

Thoracic and Lumbosacral Spine, Sacroiliac Joint

During an event such as the subject incident, the thoracic and lumbosacral spine, and sacroiliac joint of Ms. O'Brien is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. O'Brien's thoracic and lumbosacral spine, and sacroiliac joint. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine and sacroiliac joint. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbosacral spine, and sacroiliac joint; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[40,41,42,43] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[44] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[45,46] Ms. O'Brien's thoracic and lumbosacral spine, and sacroiliac joint would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[47,48,49,50,51]

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40 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

41 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

42 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

43 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

44 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

45 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition.* American Society of Safety Engineers.

46 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

47 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition.* American Society of Safety Engineers.

48 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

49 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine, 7*(3), 184-191.

50 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics, 16*(7), 549-559.

51 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[52,53,54,55] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[56,57] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[58] According to the available documents, Ms. O'Brien was capable of performing daily activities. A segmental analysis of Ms. O'Brien demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[59,60,61]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbosacral spine, and sacroiliac joint. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. O'Brien, a causal link between the subject incident and claimed thoracic and lumbosacral spine, and sacroiliac joint biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Ms. O'Brien's activities included shopping, walking, hiking, and camping. She testified to carrying groceries, pushing shopping carts, and traveling on several vacations. These activities can produce greater movement, or stretch, to the soft tissues of Ms. O'Brien and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the

52 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

53 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, 27(8), 754-758.

54 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

55 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

56 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

57 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

58 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

59 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

60 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

61 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

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characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. O'Brien's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. O'Brien using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On February 27, 2015, Ms. Joell O'Brien was the seat-belted driver of a 2013 Toyota Corolla that was merging onto South Meridian in Puyallup, Washington, when the subject Corolla was contacted in the rear at low speed by a 2013 Toyota Prius.
2. The severity of the subject incident was below 8.0 miles-per-hour with an average acceleration less than 2.4g.
3. The acceleration experienced by Ms. O'Brien was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. O'Brien's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. O'Brien's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. O'Brien's claimed thoracic and lumbosacral spine, and sacroiliac joint biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbosacral spine, and sacroiliac joint biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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August 15, 2016

[redacted]

[redacted]

Dear [redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of [redacted] This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers and the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1. Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.
2. Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.
3. Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.
4. King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.
5. King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on May 19, 2013, [redacted] was the seat-belted driver of a 2001 Ford Excursion, towing a trailer, and traveling westbound on Sedgwick Road in Port Orchard, Washington. [redacted] was the seat-belted front passenger in the subject Excursion. A 1996 Ford Ranger was traveling immediately behind the subject Ford Excursion. While stopped at a traffic signal, contact was made between the rear of the trailer attached to the subject Ford Excursion and the front of the incident Ford Ranger. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eight (8) color photographic reproductions of the subject 2001 Ford Excursion
- Seven (7) color photographic reproductions of the subject trailer
- Eight (8) color photographic reproductions of the incident 1996 Ford Ranger
- Rainier Collision Inc. Unrelated Prior Damage for the subject 2001 Ford Excursion [September 10, 2013]
- Wiley's Collision Repair Estimate of Record for the incident 1996 Ford Ranger [May 30, 2013]
- Deposition Transcript of [redacted] [March 15, 2016]
- Deposition Transcript of [redacted] [March 15, 2016]
- Medical Records pertaining to [redacted]
- Medical Records pertaining to [redacted]
- VinLink data sheet for the subject 2001 Ford Excursion
- Expert AutoStats data sheets for a 2001 Ford Excursion
- VinLink data sheet for the incident 1996 Ford Ranger
- Expert AutoStats data sheets for a 1996 Ford Ranger
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

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Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that [redacted] claim were caused by the subject incident on May 19, 2013;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2001 Ford Excursion;
3. Determine [redacted] kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate [redacted] personal tolerances in the context of their pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and their reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate [redacted] attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - C5-6, C6-7, C7-T1 disc bulging
- Lumbar Spine
  - Sprain/strain

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities.” *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

The available documents indicate [redacted] attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbosacral Spine
  - Sprain/strain
  - L4-5, L5-S1 disc bulge

<u>Damage and Incident Severity:</u>

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2001 Ford Excursion and the incident 1996 Ford Ranger in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject 2001 Ford Excursion reported only pre-existing damage, consisting of damage to the left and right back door assemblies (Figure 1). In her testimony, [redacted] testified there was no damage to the subject vehicle, but noted damage to the trailer, *"a little bend on the rear gate frame in the metal"*. The photographs of the subject Excursion depicted no residual crush to the rear bumper. A hole in the left back door, noted as pre-existing, was visible. There was no significant crush to the rear of the subject trailer, and no indication of significant deformation to the trailer hitch or vehicle receiver. The records indicate the trailer was loaded with wood, a riding lawn mower, and a gasoline tank. [redacted] testified the lawn mower moved as a result of the subject incident, but the wood did not.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 2001 Ford Excursion and trailer.

The repair documents for the incident 1996 Ford Ranger indicated there was damage to the front bumper, right and left bumper bracket, and valence panel (Figure 2). Prior damage was also noted as there were dents to the front end and tailgate, and scratches throughout the right side. The photographs depicted some crush to the center of the front bumper, which was also partially displaced. [redacted] testified that the front bumper of the incident Ranger *"looked like it was buckled in a little bit"*.

Figure 2: Reproductions of photographs of the incident 1996 Ford Ranger

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Ford Ranger can be used to resolve the loads sustained by the subject Ford Excursion. That is, the loads sustained by the incident Ranger are equal and opposite to those of the subject Excursion. Further, energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17]

Analyses of the photograph and geometric measurements along with the repair record of the incident 1996 Ford Ranger revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the front of a 1996 Ford Ranger would result in significant and visibly noticeable crush across the entirety of the subject Ranger's front structure, with a residual crush of 3.0 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20] The lack of significant structural crush to the entire front of the incident Ford Ranger indicates a collision resulting in a Delta-V significantly below 10 miles per hour. Utilizing the Conservation of Momentum, the subject Ford Excursion experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of 4.1 miles-per-hour or less.[21,22]

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 PC-Crash Collision Software.

20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

21 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

22 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

Additionally, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Ford Ranger, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[23] The IIHS tested an exemplar 1996 Ford Ranger in a 5 mile-per-hour frontal impact into a flat barrier.[24] The test Ranger sustained damage to the front bumper mounting brackets, frame rail ends, and required an alignment of the cab assembly. Further, the report noted *"the bumper face bar was flattened somewhat"*. The primary damage to the subject Ranger was to the front bumper and bumper brackets. Thus, because the test Ranger in the IIHS frontal impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is more consistent with the severity of the subject incident and places the subject incident speed at 6.4 miles-per-hour for the incident Ford Ranger. Utilizing the Conservation of Momentum, the subject Ford Excursion experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of 2.6 miles-per-hour or less.[25,26]

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 4.1 mile-per-hour Delta-V is 1.2g, and the average acceleration associated with a 2.6 mile-per-hour Delta-V is less than 1.0g.[27,28,29,30] By the laws of physics, the average acceleration experienced by the subject Ford Excursion in which [redacted] were seated was significantly less than 1.2g. Importantly, these calculations do not account for the additional weight of the trailer, which would significantly reduce the Delta-V experienced by the subject Excursion, and thus also reduce the experienced accelerations.

The acceleration experienced due to gravity is 1g. This means that [redacted] experience 1g of loading while in a sedentary state. Therefore, [redacted] experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[31] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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[23] Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

[24] Insurance Institute for Highway Safety Low-Speed Crash Test Report. 1998 Ford Ranger, April 1998.

[25] Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

[26] Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

[27] Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

[28] Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

[29] Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

[30] Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

[31] Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Kinematic Analysis:

[redacted] medical records indicated he was 69 inches in height, weighed approximately 168 lbs., and was 47 years old at the time of the subject incident. [redacted] medical records indicated she was 65.5 inches in height, weighed approximately 163 lbs., and was 45 years old at the time of the subject incident. [redacted] indicated that his hands were on the wheel and that he was talking with his wife just prior to the subject incident. [redacted] testified she was unaware of the oncoming impact, talking to [redacted] She further testified that she felt a jolt, but stated she experienced *"just a little lurch forward, but not neck/head-rattling lurch"*.

The laws of physics dictate that when the subject Ford Excursion was contacted in the rear through the trailer, it would have been pushed forward causing [redacted] seats to move forward relative to their bodies. This motion would result in [redacted] moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. [redacted] torsos and pelvises would settle back into the seatback and seat bottom cushions. The available documents indicated [redacted] were wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled [redacted] bodies to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of [redacted] would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to [redacted] was well within the limits of human tolerance and well below the acceleration levels that they likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link their reported biomechanical failures and the subject incident.[32,33]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the

32 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

33 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

The medical records indicate [redacted] attribute soft-tissue biomechanical failures consistent with a sprain/strain to the subject incident. Further, [redacted] medical records report a cervical MRI on June 18, 2013 that indicated a disc bulge at C5-6, disc protrusion at C6-7, and a minimal disc bulge at C7-T1. The records also note that [redacted] had known degenerative disc disease and spinal stenosis at the C5-6 and C6-7 levels.

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[34] In the absence of this acute biomechanical failure mechanism for cervical disc failure, scientific investigations have shown that the above cervical disc diagnoses can be the result of the normal aging process.[35,36]

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Ford Excursion would be pushed forward and [redacted] would have moved rearward relative to the vehicle, until their motion was stopped by the seatback and seat bottom. The National Highway Traffic Safety Administration (NHTSA) conducts impact safety tests for continued performance and safety monitoring of the automotive industry. Testing for an exemplar 2001 Ford Excursion showed the seated height of a 50th percentile male in the driver and passenger seat was well protected and supported by the seatback components (Figure 3). [37]

Figure 3: NTHSA 50th percentile male in driver and front passenger seats.

34 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.
35 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.
36 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.
37 National Highway Traffic Safety Administration (2001). New Car Assessment Program (NCAP) Frontal Barrier Impact Test, Report No. CAL-01-06. 2001 Ford Expedition XLT.

Performing an anthropometric regression of [redacted] revealed he would have a normal seated height of 34.3 inches, the approximate seated height of a 50th percentile male. Anthropometric regression of [redacted] revealed she would have a normal seated height of 33.2 inches, approximately 1 inch shorter than the 50th percentile male. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that [redacted] cervical spine would have undergone only a subtle degree of the characteristic response phases.[38] The load would have been applied predominantly horizontal to their cervical spine and minimized relevant cervical loads.[39] The cervical loads were within physiologic limits and [redacted] would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[40,41,42]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[43,44,45,46,47] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[48] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap

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38 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

39 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

40 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

41 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

42 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

43 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

44 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

45 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

46 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

47 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

48 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

produce even higher peak head accelerations, up to 4.75g.[49,50,51,52] The available documents reported [redacted] were capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[53]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of [redacted] cannot be made.

Thoracic and Lumbosacral Spine

The medical records indicate [redacted] attributes a lumbar sprain/strain to the subject incident. [redacted] attributes a thoracic and lumbosacral sprain/strain. Further, [redacted] received a lumbar MRI on August 2, 2013 that reported a central disc protrusion at L4-5 and a central disc bulge at L5-S1. The records also indicate [redacted] also had a history of lumbar muscle strain.

During an event such as the subject incident, the thoracic and lumbosacral spine of [redacted] is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of [redacted] thoracic and lumbosacral spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbosacral spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbosacral spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[54,55,56,57] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbosacral biomechanical failure. West et al. subjected human volunteers to multiple rear-end

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49 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

50 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

51 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

52 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

53 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

54 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

55 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

56 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

57 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[58] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[59,60] [redacted] thoracic and lumbosacral spine would not have been exposed to any loading or motion outside of the range of their personal tolerance levels.[61,62,63,64,65]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[66,67,68,69] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[70,71] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[72] According to the available documents, [redacted] was capable of performing daily activities. A segmental analysis of [redacted]

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58 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

59 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

60 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

61 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

62 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

63 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

64 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

65 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

66 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

67 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

68 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

69 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

70 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

71 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

72 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

demonstrated that as they lifted objects during daily tasks, the forces applied to their lower spines would have been comparable to or greater than those during the subject incident.[73,74,75]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbosacral spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbosacral spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of [redacted] a causal link between the subject incident and claimed thoracic and lumbosacral biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, [redacted] had worked as a carpenter and construction worker. He testified that he was currently working as a woodworker at the time of the subject incident. [redacted] hobbies included hiking, being outdoors, and fishing. He indicated he was capable of performing house work, grocery shopping, and gardening.

[redacted] had previously worked as a caregiver, doing housekeeping, laundry, cooking, and driving. At the time of the subject incident, she was working in the tool room for a naval yard loading and managing inventory. She testified she was capable of lifting up to 30-40 lbs., and her hobbies included fishing, gardening, and playing with her grandchildren. She further testified she was capable of performing housework, grocery shopping, and yard work.

These activities can produce greater movement, or stretch, to the soft tissues of [redacted] and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[76]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between [redacted] reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of [redacted] using peer-reviewed and generally-accepted methodologies.

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73 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

74 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

75 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

76 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

ARCCA INCORPORATED

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 19, 2013, [redacted] were the seat-belted driver and front passenger, respectively, of a 2001 Ford Excursion that was stopped on Sedgwick Road in Port Orchard, Washington, when the subject Ford Excursion was contacted in the rear at low speed by a 1996 Ford Ranger.
2. The severity of the subject incident was significantly below 4.1 miles-per-hour with an average acceleration less than 1.2g, and more consistent with 2.6 miles-per-hour with an average acceleration of less than 1.0g.
3. The acceleration experienced by [redacted] was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move [redacted] bodies back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed thoracic and lumbosacral biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbosacral biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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September 8, 2016

Aaron Lee, Esquire
Law Offices of Sweeney & Dietzler
1191 Second Avenue
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Seattle, WA 98101

Re: *Miller, Jasmin and Meilin Lani v. Lewis Pallazo*
Claim No.: 3196 8801 5041
ARCCA Case No.: 2107-1061

Dear Mr. Lee:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Jasmin Miller and Meilin Lani. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on October 22, 2012, Ms. Meilin Lani was the seat-belted driver of a 1994 Honda Accord traveling northbound on South Mildred Street in Tacoma, Washington. Ms. Jasmin Miller was the seat-belted front passenger in the subject Honda. Lewis Pallazo was the driver of a 2012 Kia Sportage traveling immediately behind the subject Honda Accord. While the Honda stopped for a pedestrian, contact was made between the rear of the subject Honda Accord and the front of the incident Kia Sportage. No airbags deployed in either vehicle, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Three (3) color photographic reproductions of the subject 1994 Honda Accord
- Five (5) color photographic reproductions of the incident 2012 Kia Sportage
- Gerber Collision & Glass – Tacoma Estimate of Record for the subject 1994 Honda Accord [October 25, 2012]
- Premier Collision Carstar Estimate of Record for the incident 2012 Kia Sportage [October 23, 2012]
- Deposition Transcript of Jasmine Miller; Meilin Lani and Jasmine Miller vs. Lewis Palazzo and Michelle Palazzo [March 30, 2016]
- Deposition Transcript of Meilin Lani; Meilin Lani and Jasmine Miller vs. Lewis Palazzo and Michelle Palazzo [March 30, 2016]
- Medical Records pertaining to Jasmine Miller
- Medical Records pertaining to Meilin Lani
- VinLink data sheet for the subject 1994 Honda Accord
- Expert AutoStats data sheets for a 1994 Honda Accord
- VinLink data sheet for the incident 2012 Kia Sportage
- Expert AutoStats data sheets for a 2012 Kia Sportage
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

1. Identify the biomechanical failures that Ms. Miller and Ms. Lani claim were caused by the subject incident on December 22, 2012;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1994 Honda Accord;
3. Determine Ms. Miller and Ms. Lani's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Miller and Ms. Lani's personal tolerances in the context of their pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and their reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Miller attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Lumbar Spine
  - Lumbago

The available documents indicate Ms. Lani attributes the following biomechanical failures as a result of the subject incident:

- Fractured Dentures

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 1994 Honda Accord and the incident 2012 Kia Sportage in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject 1994 Honda Accord reported damage to the rear bumper cover, energy absorber, impact bar, push rivet, rear body panel, and trunk lid, which is consistent with the reviewed photographs (Figure 1). Ms. Lani testified that the subject incident was ***"hard enough to cave in my – the back of my car"***. The photographs depicted scuffs and scrapes primarily to the left side of the rear bumper cover, with several small scuffs to the right-center. The trunk lid was partially displaced, most notably with respect to the quarter panels and tail lights. The left side of the bumper cover was detached near the left rear wheel.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers

Figure 1: Reproductions of photographs of the subject 1994 Honda Accord

The repair documents for the incident 2012 Kia Sportage indicated there was damage to the valence panel, lower grille, impact bar, license bracket, radiator sight shield, air conditioning condenser, and front bumper cover. The photographs depicted the front bumper cover slightly displaced near the right fender junction, just below the right headlight (Figure 2). The front license plate had a minor bend rearwards under the front bumper. There was no significant residual crush to the front bumper cover, and it remained in alignment with the grille.

Figure 2: Reproductions of photographs of the incident 2012 Kia Sportage

Multiple methods were used to analyze the severity of the subject incident. First, energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 1994 Honda Accord revealed the damage due to the subject incident. An energy crush analysis[18,19] indicates that a single 10 mile per hour flat barrier impact to the rear of a 1994 Honda Accord would result in significant and visibly noticeable crush across the entirety of the subject Honda's rear structure, with a residual crush of 4.5 inches. Therefore, the energy crush analysis shows greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[20] This is further supported by a damage threshold speed change analysis to the subject Honda Accord. [21]

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour Delta-V is 3.0g.[22,23,24,25] By the laws of physics, the average acceleration experienced by the subject Honda Accord in which Ms. Miller and Ms. Lani were seated was less than 3.0g.

The acceleration experienced due to gravity is 1g. This means that Ms. Miller and Ms. Lani experience 1g of loading while in a sedentary state. Therefore, they experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [26] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.
14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.
15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.
16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.
17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.
18 EDCRASH, Engineering Dynamics Corp.
19 PC-Crash Collision Software.
20 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.
21 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 1995 Midsize Four-Door Sedans, May 1995.
22 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.
23 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.
24 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.
25 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.
26 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Kinematic Analysis:

Ms. Miller's medical records indicated she was 58 inches in height, weighed approximately 95-110 lbs., and was 15 years old at the time of the subject incident. Ms. Miller testified she was unaware, and her head contacted the passenger window. The records further indicated her seat belt locked during the subject incident.

Ms. Lani's medical records indicated she was 53 years old at the time of the subject incident. Ms. Lani testified her belt locked, but her chest hit the steering wheel. She further testified her body *"whipped back like – you know like I went forward, hit the wheel. My teeth flew out. I got yanked back, the seatbelt"*.

This reported forward motion is contrary to the most basic laws of physics and the use of the available seatbelt. The laws of physics dictate that when the subject Honda Accord was contacted in the rear, it would have been pushed forward causing the occupant's seat to move forward relative to their bodies. This motion would result in Ms. Miller and Ms. Lani moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Their torsos and pelvises would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Miller and Ms. Lani were wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled their bodies to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Miller and Ms. Lani was well within the limits of human tolerance and well below the acceleration levels that they likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link their reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

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[27] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[28] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

Cervical Spine

The medical records indicate Ms. Miller attributes a cervical sprain/strain to the subject incident. A cervical X-ray performed October 22, 2012 reported no evidence of ligamentous biomechanical failure. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda Accord would be pushed forward and Ms. Miller would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 1994 Honda Accord revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 29.75 inches in the full down position, and 31.5 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Miller revealed she would have a normal seated height of 30.3 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Miller's cervical spine would have undergone only a subtle degree of the characteristic response phases.[29] The load would have been applied predominantly horizontal to their cervical spine and minimized relevant cervical loads.[30] The cervical loads were within physiologic limits and Ms. Miller would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[31,32,33]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[34,35,36,37,38] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the

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29 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

30 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

31 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

32 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

33 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

34 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

35 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

36 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

37 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

cervical spine sprain/strain biomechanical failure threshold is 5g.[39] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [40,41,42,43] The available documents reported Ms. Miller was capable of performing regular daily activities, including running, walking, and ROTC training. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Miller cannot be made.

Lumbar Spine

The available documents indicate Ms. Miller attributes lumbago, or low back pain consistent with a soft-tissue sprain/strain, to the subject incident.

During an event such as the subject incident, the lumbar spine of Ms. Miller is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Miller's lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the lumbar spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

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39 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

40 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

41 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

42 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

43 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

44 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living* (No. 2006-01-0247). SAE Technical Paper.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[45,46,47,48] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[49] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[50,51] Ms. Miller's lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[52,53,54,55,56]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [57,58,59,60] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[61,62] Peer-reviewed technical literature and learned treatises have

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45 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

46 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

47 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

48 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

49 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

50 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition.* American Society of Safety Engineers.

51 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

52 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition.* American Society of Safety Engineers.

53 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

54 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

55 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

56 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

57 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

58 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

59 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

60 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

61 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

62 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[63] A segmental analysis of Ms. Miller demonstrated that as she lifted objects during daily tasks, the forces applied to their lower spine would have been comparable to or greater than those during the subject incident.[64,65,66]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Miller, a causal link between the subject incident and claimed lumbar biomechanical failures cannot be made.

Fractured Dentures

Ms. Lani testified that her dentures were fractured as a result of them ejecting from her mouth during the subject incident (*"hard enough to knock out the dentures out of my mouth"*). The medical records indicate the full upper denture was fractured. Generally, dentures remain in place as a result of a suction seal between the denture and the gums. The seal may also be aided by a weak adhesive. They are designed to replicate function of normal teeth, specifically biting and aiding in speech. In order to dislodge dentures from the mouth, the mouth must be open and the suction seal between the gums and dentures must be overcome by a greater force. Finally, the head would need to move forward with significant speed and then be decelerated at a significant rate such that the dentures can overcome the inherent inertia of the dentures and any adhesion. However, as noted above, the head would tend to move rearward due to contact between the vehicles.

Personal Tolerance Values

According to the available documents, Ms. Miller was a full time student and became employed at Little Caesar's after the incident. She was also training for ROTC and was capable of bending, squatting, walking, and running. Ms. Lani testified she was employed as a home care worker at the time of the incident. Her job duties included cooking, cleaning, and transporting patients to appointments. She further testified her activities included swimming, hiking, camping, fishing, boating, and hunting. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Miller and Ms. Lani and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Miller and Ms. Lani's reported biomechanical failures and the subject incident incorporated

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63 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

64 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

65 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

66 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerances levels of Ms. Miller and Ms. Lani using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On October 22, 2012, Ms. Meilin Lani was the seat-belted driver of a 1994 Honda Accord, with Ms. Jasmine Miller as the seat-belted front passenger, which was stopped on South Mildred Street in Tacoma, Washington, when the subject Honda Accord was contacted in the rear at low speed by a 2012 Kia Sportage.
2. The severity of the subject incident was below 10 miles-per-hour with an average acceleration less than 3.0g.
3. The acceleration experienced by Ms. Miller and Ms. Lani was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Miller and Ms. Lani's bodies back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Miller's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Miller's claimed lumbar biomechanical failures. As such, a causal relationship between the subject incident and the lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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September 16, 2016

Gavin Radkey, Esquire
Law Offices of Sweeney & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Sell, Kristi v. Dung V. Ho and Thuy Pham*
Claim No.: 5609 4677 5037
ARCCA Case No.: 2107-1075

Dear Mr. Radkey:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Kristi Sell. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on November 19, 2014, Ms. Kristi Sell was the seat-belted driver of a 2012 Honda Civic traveling on Portland Avenue near the intersection of 95th Street East in Tacoma, Washington. Ms. Thuy Pham was the driver of a 2010 Toyota Corolla traveling immediately behind the subject Honda Civic. While stopped to turn left onto 95th Street East, contact was made between the rear of the subject Honda and the front of the incident Toyota. No airbags were deployed in the subject Honda, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Six (6) color photographic reproductions of the subject 2012 Honda Civic
- Six (6) color photographic reproductions of the incident 2010 Toyota Corolla
- Barrett's Collision Center, Inc Supplement of Record 1 with Summary for the subject 2012 Honda Civic [December 8, 2014]
- Titus-Will Collision Center Supplement of Record 2 with Summary for the incident 2010 Toyota Corolla [December 18, 2014]
- Complaint for Personal Injuries, *Kristi A. Sell vs. Thuy Pham and Dung V. Ho* [October 15, 2015]
- Deposition Transcript of Kristi Sell, *Kristi A. Sell vs. Thuy Pham and Dung V. Ho* [April 20, 2016]
- Medical Records pertaining to Kristi Sell
- VinLink data sheet for the subject 2012 Honda Civic
- Expert AutoStats data sheets for a 2012 Honda Civic
- VinLink data sheet for the incident 2010 Toyota Corolla
- Expert AutoStats data sheets for a 2010 Toyota Corolla
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

1. Identify the biomechanical failures that Ms. Sell claims were caused by the subject incident on November 19, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2012 Honda Civic;
3. Determine Ms. Sell's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Sell's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Sell attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2012 Honda Civic and the incident 2010 Toyota Corolla in association with accepted scientific methodologies. [11,12]

The repair estimate for the subject Honda Civic reported damage to the rear bumper cover, energy absorber, impact bar, left and right bumper brackets, trunk lid, and rear body panel, which is consistent with the reviewed photographs (Figure 1). The photographs depicted the rear bumper cover displaced and out of alignment relative to the trunk lid, quarter panels, and tail lights. There were some contact marks in the form of scuffing to the center and center right of the rear bumper cover. The photographs also depicted deformation to the rear body panel near the rear bumper brackets.

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 2012 Honda Civic

The repair documents for the incident 2010 Toyota Corolla indicated there was damage primarily to the left front head lamp, front bumper absorber, reinforcement, bumper cover, license bracket, left fender rail end, hood support rod holder, left fender, grille, radiator support, and left upper support. The photographs depicted black scuffs and paint transfer to the left and center of the front bumper (Figure 2). The grille and front bumper cover were displaced relative to the left fender, hood, and left headlamp. The left headlamp was also displaced and partially cracked. The front bumper was bent just right of center. A clip connecting to the radiator support bracket was also fractured.

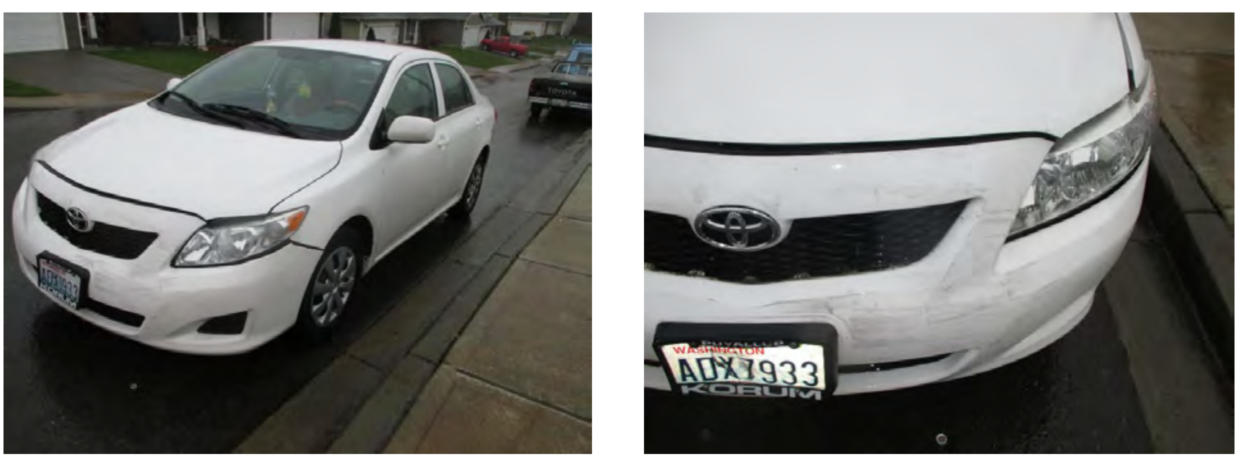

Figure 2: Reproductions of photographs of the incident 2010 Toyota Corolla

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Honda Civic, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested an exemplar 2012 Honda Civic in a 6.2 mile-per-hour rear impact into a full-width barrier.[14] The test Honda Civic sustained damage to the rear body panel, rear bumper cover and rear bumper reinforcement, energy absorber, and bumper mounting brackets. The primary damage to the subject Honda Civic was to the rear bumper cover, energy absorber, impact bar, left and right bumper brackets, trunk lid, and rear body panel. Thus, because the test Honda Civic in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident. Accounting for restitution, the subject Honda experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of 8.0 miles-per-hour or less.[15,16] Additionally, the above analysis is consistent with an energy crush analysis to the front of the incident Toyota Corolla.[17,18,19,20,21]

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13 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

14 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2008 Honda Civic, September 2008.

15 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

16 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

17 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

18 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

19 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

20 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

21 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with an 8.0 mile-per-hour Delta-V is 2.4g.[22,23,24,25] By the laws of physics, the average acceleration experienced by the subject Honda Civic in which Ms. Sell was seated was significantly less than 2.4g.

The acceleration experienced due to gravity is 1g. This means that Ms. Sell experiences 1g of loading while in a sedentary state. Therefore, Ms. Sell experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [26] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Sell's medical records indicated she was 65 inches in height, weighed approximately 140 lbs., and was 48 years old at the time of the subject incident. Ms. Sell testified her foot was over the gas pedal, and she was aware of the oncoming impact. She further testified that her *"body went forward and my neck went back"*. Her testimony also indicated her seat belt locked, and her body made no contact with the interior of the subject vehicle.

The laws of physics dictate that when the subject Honda Civic was contacted in the rear, it would have been pushed forward causing Ms. Sell's seat to move forward relative to her body. This motion would result in Ms. Sell moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Sell's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Sell was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Sell's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Sell would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Sell was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no

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[22] Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

[23] Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

[24] Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

[25] Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

[26] Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

<u>Cervical Spine</u>

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda Civic would be pushed forward and Ms. Sell would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2012 Honda Civic revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.75 inches in the full down position, and 34.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Sell revealed she would have a normal seated height of 32.9 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Sell's cervical spine would have undergone only a subtle degree of the characteristic response phases.[29] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[30] The cervical loads were within physiologic

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27 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

28 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

29 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

30 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

limits and Ms. Sell would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[31,32,33]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[34,35,36,37,38] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[39] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [40,41,42,43] The available documents reported Ms. Sell was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[44]

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31 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

32 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

33 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

34 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

35 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

36 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

37 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

39 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

40 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

41 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

42 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

43 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

44 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Sell cannot be made.

Thoracic and Lumbar Spine

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Sell is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Sell's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[45,46,47,48] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[49] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[50,51] Ms. Sell's thoracic and lumbar spine

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[45] Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

[46] Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

[47] Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

[48] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[49] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

[50] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[51] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[52,53,54,55,56]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along with crouching and arching the back can generate loads that are comparable or greater than those resulting from subject incident.[57,58,59,60] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable or greater than the subject incident.[61,62] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[63] According to the available documents, Ms. Sell was capable of performing daily activities, including Irish dancing. A segmental analysis of Ms. Sell demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[64,65,66]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Sell, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

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52 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

53 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

54 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

55 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

56 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

57 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

58 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

59 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

60 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

61 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

62 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

63 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

64 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

65 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

66 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

Personal Tolerance Values

According to the available documents, Ms. Sell was employed for a catering company, working 40 hours per week leading up to the time of the subject incident. As mentioned previously, she regularly danced, including Irish, ballroom, tap, jazz, and ballet. She also testified she was capable of performing common activities of daily living, such as cleaning dishes, making, dinner, and washing her car. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Sell and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Sell's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Sell using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 19, 2014, Ms. Kristi Sell was the seat-belted driver of a 2012 Honda Civic that was stopped on Portland Avenue near the intersection of 95th Street East in Tacoma, Washington, when the subject Honda was contacted in the rear at low speed by a 2010 Toyota Corolla.
2. The severity of the subject incident was below 8.0 miles-per-hour with an average acceleration less than 2.4g.
3. The acceleration experienced by Ms. Sell was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Sell's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Sell's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Sell's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

5E3211602469

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November 14, 2016

Stephanie Kern
Liberty Mutual Insurance Company
P.O. Box 7230
London, KY 40742

Re: *Phillips, Christine*
File No.: 021511712
ARCCA Case No.: 2107-1128

Dear Ms. Kern:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Christine Phillips. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

ARCCA

Incident Description:

According to the available documents, on September 8, 2011, Ms. Christine Phillips was the seat-belted driver of a 2011 Ford Edge traveling on 80th Ave East at State Road 162 in Puyallup, Washington. A 1997 Chevrolet Suburban was traveling immediately behind the subject Ford Edge. While the Ford Edge was stopped in traffic, contact was made between the rear of the subject Ford Edge and the front of the incident Chevrolet Suburban.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Two (2) color photographic reproductions of the subject 2011 Ford Edge
- Medical Records pertaining to Christine Phillips
- VinLink data sheet for the subject 2011 Ford Edge
- Expert AutoStats data sheets for a 2011 Ford Edge
- VinLink data sheet for the incident 1997 Chevrolet Suburban
- Expert AutoStats data sheets for a 1997 Chevrolet Suburban
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Phillips claims were caused by the subject incident on September 8, 2011;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2011 Ford Edge;
3. Determine Ms. Phillips's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

5. Evaluate Ms. Phillips's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Phillips attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
- Right Shoulder
  - Subacromial impingement
  - Anterior labral tear

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the subject 2011 Ford Edge in association with accepted scientific methodologies. [11,12]

The photographic reproductions of the subject 2011 Ford Edge depicted a scrape/gouge to the left side of the rear bumper cover above the left exhaust pipe (Figure 1). The rear bumper cover was in alignment with the left quarter panel, left tail light, and lift gate. There was no significant crush to the rear of the subject Ford. The records indicate Ms. Phillips reported the incident Chevrolet contacted the rear of the subject Ford at 30 miles-per-hour.

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11 Siegmund, G.P., et al. (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352), Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 2011 Ford Edge

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photographs and geometric measurements of the subject 2011 Ford Edge revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 mile per hour flat barrier impact to the rear of an exemplar Ford Edge would result in significant and visibly noticeable crush across the entirety of the subject Edge's rear structure, with a residual crush of 4.0 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural crush to the entire rear of the subject Ford Edge indicates a collision resulting in a Delta-V significantly below 10 miles per hour.

Furthermore, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Ford Edge, defined by the photographic reproductions, was used to perform a damage threshold speed change analysis.[20] The IIHS tested vehicles from the same era and manufacturer in 3.1 to 6.2 mile-per-hour rear impacts. The test vehicles sustained damage comparable if not greater than the subject Ford Edge. Thus, because the test vehicles in the IIHS rear impact test sustained comparable, if not greater, damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident and places the subject incident more consistent with the test speed of 3.1 to 6.2 miles-per-hour.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.
14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.
15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper
16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.
17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.
18 EDCRASH. Engineering Dynamics Corp.
19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View. (SAE 880072). Warrendale, PA. Society of Automotive Engineers.
20 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions. (SAE 960887). Warrendale, PA. Society of Automotive Engineers.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the peak acceleration associated with a 6.2 mile-per-hour Delta-V is 3.8g.[21,22,23,24] By the laws of physics, the average acceleration experienced by the subject Ford Edge in which Ms. Phillips was seated was significantly less than 3.8g.

The acceleration experienced due to gravity is 1g. This means that Ms. Phillips experiences 1g of loading while in a sedentary state. Therefore, Ms. Phillips experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[25] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Phillips's medical records indicated she was 66 inches in height, weighed approximately 225 lbs., and was 56 years old at the time of the subject incident. Ms. Phillips indicated she was looking to the right, her hands were on the steering wheel, and she was unaware. She further stated that she made no contact with the inside of the subject vehicle.

The laws of physics dictate that when the subject Ford Edge was contacted in the rear, it would have been pushed forward causing Ms. Phillips's seat to move forward relative to her body. This motion would result in Ms. Phillips moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Phillips's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Phillips was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Phillips's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Phillips would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Phillips was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there

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21 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration.* (No. 2000-01-0880). SAE Technical Paper.

22 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

23 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts.* (No. 970120). SAE Technical Paper.

24 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

25 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[26,27]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

In a rear impact that produces motion of the subject vehicle, the Ford Edge would be pushed forward and Ms. Phillips would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar Ford Edge revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 32.75 inches in the full down position, and 35.25 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Phillips revealed she would have a normal seated height of 33.5 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Phillips's cervical spine would have undergone only a subtle degree of the characteristic response phases.[28] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant

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26 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
27 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.
28 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

cervical loads.[29] The cervical loads were within physiologic limits and Ms. Phillips would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[30,31,32]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[33,34,35,36,37] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[38] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [39,40,41,42] The available documents reported Ms. Phillips was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43]

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29 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

30 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery, 13(3): 254-260.

31 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA. Society of Automotive Engineers.

32 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

33 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

34 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

35 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wortler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

36 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

37 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

38 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

39 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

40 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

41 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

42 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

43 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living.* (No. 2006-01-0247). SAE Technical Paper.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Phillips cannot be made.

Thoracic and Lumbar Spine

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Phillips is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Phillips's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[44,45,46,47] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[48] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs, which measured spinal response to rear impact accelerations at severities greater than the subject incident.[49,50] Ms. Phillips's thoracic and lumbar

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44 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

45 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

46 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper

47 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

48 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

49 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

50 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[51,52,53,54,55]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[56,57,58,59] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[60,61] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[62] According to the available documents, Ms. Phillips was capable of performing daily activities. A segmental analysis of Ms. Phillips demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[63,64,65]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Phillips, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

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[51] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[52] Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System, Lea & Febiger, Philadelphia, London.

[53] Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, 7(3), 184-191.

[54] Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16(7), 549-559.

[55] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

[56] Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, 44(8), 781-794.

[57] Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, 27(8), 754-758.

[58] Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, 46(3), 511-514.

[59] Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

[60] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, 42, 410.

[61] Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

[62] Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, 29(20), 2319-2329.

[63] Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

[64] Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3), 327-351.

[65] Chaffin, DB, Andersson, GBJ, Martin, BJ. (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience.

Right Shoulder

Ms. Phillips underwent multiple right shoulder MRI's prior to undergoing surgery that identified subacromial impingement and an anterior labral tear. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." Shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa (bursitis) that surrounds these tendons. Impingement syndrome is a result of the supraspinatus becoming entrapped between the anterior head of the humerus and acromion, coracoacromial ligament or the acromioclavicular joint.[66,67,68] An acute labral tear requires loading directed into the glenoid fossa that generates a shearing force between the humeral head and glenoid labrum.[69,70,71] The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[72] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[45]

Ms. Phillips's torso would have moved rearward relative to the subject vehicle's interior, which would have been supported and constrained by the seatback.[73,74,75,76] The seatback would have distributed any loading across her entire back and shoulders. Any rebound would have been limited by the seat belt which would have engaged Ms. Phillips's bony left clavicle and pelvis. The restraint provided by the seat belt restraint and seatback were such that any motion of Ms. Phillips's right shoulder would have been limited to well within the range of normal physiological limits.

The records indicate Ms. Phillips was capable of doing laundry, vacuuming, cleaning, and lifting. Common activities would directly load Ms. Phillips's right shoulder multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel or reaching

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66 Seeger, L.L., Gold, R.H., et al. (1988). "Shoulder Impingement Syndrome: MR Findings in 53 Shoulder." AJR. 150:343-347.

67 Murray, J-C. and Pelet, S. (2014). "Shoulder Impingement Syndrome Caused by a Voluminous Subdeltoid Lipoma." Case Reports In Orthopedics, Article ID 760219.3.

68 Escamilla, R.F., Hooks, T.R., Wilk, K.E. (2014). "Optimal management of shoulder impingement syndrome." Journal of Sports Medicine, 2014:5 13-24.

69 D'Alessandro, D.F., Fleischli, E., et al. (2000). "Superior Labral Lesions: Diagnosis and Management." Journal of Athletic Training 35(3): 286-292.

70 Payne, L. Z., (1994). "Tears of the Glenoid Labrum." Orthopaedic Review 577-583.

71 Park, J.H., Lee, Y.S., Wang, J.H., et al., (2008). "Outcome of Isolated SLAP Lesions and Analysis of the Results According to Injury Mechanisms." Knee Surg Sports Traumatol Arthrosc 16: 511-515.

72 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

73 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

74 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.

75 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

76 Ivory, M.A., Furbish, C., et al. (2010). *Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions* (No. 2010-01-0067). SAE Technical Paper.

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and lifting tasks are comparable to, or greater than that of the subject incident.[77,78,79,80] These data demonstrate that the shoulder forces and accelerations of the subject incident did not exceed Ms. Phillips's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported right shoulder biomechanical failures of Ms. Phillips cannot be made.

Personal Tolerance Values

As mentioned previously, Ms. Phillips was capable of doing laundry, cleaning her home, and lifting 5 pounds of flowers in and out of her vehicle. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Phillips and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Phillips's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Phillips using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On September 8, 2011, Ms. Christine Phillips was the seat-belted driver of a 2011 Ford Edge that was stopped on 80th Avenue East in Puyallup, Washington, when the subject Ford Edge was contacted in the rear at low speed by a 1997 Chevrolet Suburban.
2. The severity of the subject incident was consistent with 6.2 miles-per-hour with a peak acceleration less than 3.8g.
3. The acceleration experienced by Ms. Phillips was within the limits of human tolerance and comparable to that experienced during various daily activities.

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77 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

78 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

79 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

80 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Phillips's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Phillips's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Phillips's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Phillips's claimed right shoulder biomechanical failures. As such, a causal relationship between the subject incident and the right shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

ARCCA, INCORPORATED
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May 31, 2017

Stephanie Kern
Liberty Mutual Insurance Company
P.O. Box 7230
London, KY 40742

Re: *Phillips, Christine*
File No.: 021511712
ARCCA Case No.: 2107-1128

Dear Ms. Kern:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Christine Phillips. This letter is meant to supplement my report of November 14, 2016. Since that time, I have had the opportunity to review and evaluate additional documents related to the subject incident on September 8, 2011. Furthermore, the additional documents do not change my opinion of my previous analysis:

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Two (2) color photographic reproductions of the subject 2011 Ford Edge
- Nine (9) color photographic reproductions of the incident 1997 Chevrolet Suburban
- Estimate of Record for the subject 2011 Ford Edge [September 14, 2011]
- The ACES Reconstruction Report completed by David C. Wells [April 28, 2017]

Conclusions:

Based upon the additional information, my opinions from my report dated November 14, 2016, have not changed and are further supported. The additional records further confirmed the already noted biomechanical analysis.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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November 28, 2016

NO WHERE HAVE YOU ACCOUNTED FOR THE FACT THAT IN MVA THE APPLIED FORCES ~~OCCUR~~ HAVE A DURATION OF .1-.2 SECOND

Mai-Anh Nako, Esquire
Allstate Staff Counsel
1000 SW Broadway, Suite 1080
Portland, OR 97205

Re: *Mitchell, Carolyn v. Elizabeth Jeanne Freiling*
ARCCA Case No.: 1017-189

Dear Ms. Nako:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Carolyn Mitchell. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

DEP EX 109

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Incident Description:

According to the available documents, on May 9, 2014, Ms. Carolyn Mitchell was the seat-belted driver of a 2002 Ford Focus traveling northbound on N. Interstate Ave. in Portland, OR. Ms. Elizabeth Freiling was the driver of a 2006 Volvo XC90 traveling immediately behind the subject Ford Focus. While stopped in traffic, contact was made between the rear of the subject Ford Focus and the front of the incident Volvo XC90.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eighteen (18) color photographic reproductions of the subject 2002 Ford Focus
- Fifteen (15) color photographic reproductions of the incident 2006 Volvo XC90
- Estimate of Record for the subject 2002 Ford Focus [August 22, 2014]
- Estimate of Record for the incident 2006 Volvo XC90 [August 25, 2014]
- Deposition transcript from Carolyn Mitchell, *Carolyn Mitchell v. Elizabeth Jeanne Freiling* [October 19, 2016]
- Medical Records pertaining to Carolyn Mitchell
- VinLink data sheet for the subject 2002 Ford Focus
- Expert AutoStats data sheets for a 2002 Ford Focus
- VinLink data sheet for the incident 2006 Volvo XC90
- Expert AutoStats data sheets for a 2006 Volvo XC90
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Mitchell claims were caused by the subject incident on May 9, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2002 Ford Focus;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

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3. Determine Ms. Mitchell's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Mitchell's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

How did you do that

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Mitchell attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
- Right Shoulder
  - Trapezius sprain/strain
  - Supraspinatus sprain/strain
  - Rotator cuff tear

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2002 Ford Focus and the incident 2006 Volvo XC90 in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject 2002 Ford Focus reported damage to the rear bumper cover with prior damage to the left quarter panel and left side of the rear bumper cover. The photographs depicted scratches and two small holes to the rear bumper cover (Figure 1).

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers

Figure 1: Reproductions of photographs of the subject 2002 Ford Focus

The repair documents for the incident 2006 Volvo XC90 indicated there was damage to the front bumper cover and center grille. The repair documents also indicated that there was prior damage to the right headlight, right bumper corner, right fender, and left/right tail light and reflector, as well as miscellaneous dents, dings, and scrapes. The photographs depicted small dents to the passenger side of the front bumper around the grille (Figure 2).

Figure 2: Reproductions of photographs of the incident 2006 Volvo XC90

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The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject 2002 Ford Focus, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested an exemplar 2002 Ford Focus in a 5 mile-per-hour rear impact into a flat barrier.[14] The test Ford Focus sustained damage to the rear bumper cover, rear reinforcement bumper, rear body panel, rear floorpan, and left quarter panel. The primary damage to the subject Ford Focus was to the rear bumper cover. Thus, because the test Ford Focus in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the subject Ford Focus speed below the test speed of 5 miles-per-hour. Additionally, the above analysis is consistent with an IIHS low-speed crash test for an exemplar 2006 Volvo XC90.[15]

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Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 5 mile-per-hour Delta-V is 1.5g.[16,17,18,19] By the laws of physics, the average acceleration experienced by the subject Ford Focus in which Ms. Mitchell was seated was significantly less than 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Mitchell experiences 1g of loading while in a sedentary state. Therefore, Ms. Mitchell experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Mitchell's medical records indicated she was 65 inches in height, weighed approximately 238 lbs., and was 58 years old at the time of the subject incident. Ms. Mitchell testified that upon impact she was thrown back and then forward, and her head hit the head rest.

The laws of physics dictate that when the subject Ford Focus was contacted in the rear, it would have been pushed forward causing Ms. Mitchell's seat to move forward relative to her body. This motion would result in Ms. Mitchell moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Mitchell's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Mitchell was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the

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13 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887), Warrendale, PA, Society of Automotive Engineers.

14 Insurance Institute for Highway Safety Low-Speed Crash Test Report 2000 Ford Focus, January 2001.

15 Insurance Institute for Highway Safety Low-Speed Crash Test Report 2003 Volvo XC90, March 2003.

16 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

17 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

18 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

19 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

20 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

available restraint system and coupled Ms. Mitchell's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Mitchell would have been limited to well within the range of normal physiological limits.

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Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Mitchell was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[21,22]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

NO ONE TESTED TO FAILURE

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

HOW DO YOU KNOW IF BIOMECHANICAL THRESHOLD LEVEL

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Ford Focus would be pushed forward and Ms. Mitchell would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2002 Ford Focus revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.75 inches in the full down position, and 34.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Mitchell revealed she would have a normal seated height of 33.1 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Mitchell's cervical spine would have undergone only a subtle degree of

DID YOU FIND ONE

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21 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

22 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

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the characteristic response phases.[23] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[24] The cervical loads were within physiologic limits and Ms. Mitchell would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[25,26,27]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[28,29,30,31,32] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[33] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [34,35,36,37] The available documents reported Ms. Mitchell was capable of performing regular daily activities. Additional research has shown that

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23 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

24 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

25 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery 13(3): 254-260.

26 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

27 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

28 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

29 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

30 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

31 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

32 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

33 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, 29(9), 979-987.

34 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, 42, 410.

35 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, 42, 25-30.

36 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

37 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, 39(2), 766-776.

cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[38]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Mitchell cannot be made.

Thoracic and Lumbar Spine

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Mitchell is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Mitchell's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[39,40,41,42] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[43] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[44,45] Ms. Mitchell's thoracic and lumbar

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38 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

39 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

40 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

41 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

42 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

43 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

44 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

45 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

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spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[46,47,48,49,50]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[51,52,53,54] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[55,56] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[57] According to the available documents, Ms. Mitchell was capable of performing daily activities. A segmental analysis of Ms. Mitchell demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[58,59,60]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Mitchell, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

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46 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

47 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

48 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, 7(3), 184-191.

49 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16(7), 549-559.

50 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

51 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, 44(8), 781-794.

52 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, 27(8), 754-758.

53 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, 46(3), 511-514.

54 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

55 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, 42, 410.

56 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

57 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, 29(20), 2319-2329.

58 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

59 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

60 Chaffin, DB, Andersson, GBJ, Martin, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

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Right Shoulder

According to the available documents, a right shoulder X-ray was performed on August 1, 2014 and the results were normal. A right shoulder MRI was performed on February 11, 2015 and the results showed chronic and near completed retracted tear of the supraspinatus tendon, partial non-retracted instrasubstance tears of the infraspinatus tendon and impingement type anatomy from the degenerative acromioclavicular joint.

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." Shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa (bursitis) that surrounds these tendons. Impingement syndrome is a result of the supraspinatus becoming entrapped between the anterior head of the humerus and acromion, coracoacromial ligament or the acromioclavicular joint.[61,62,63] An acute labral tear requires loading directed into the glenoid fossa that generates a shearing force between the humeral head and glenoid labrum.[64,65,66] The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[67] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[15]

Ms. Mitchell's torso would have moved rearward relative to the subject vehicle's interior, which would have been supported and constrained by the seatback.[68,69,70,71] The seatback would have distributed any loading across her entire back and shoulders. Any rebound would have been limited by the seat belt which would have engaged Ms. Mitchell's bony left clavicle and pelvis. The restraint provided by the seat belt restraint and seatback were such that any motion of Ms. Mitchell's right shoulder would have been limited to well within the range of normal physiological limits.

The records indicate Ms. Mitchell was capable of regularly exercising, including water aerobics. Common activities would directly load Ms. Mitchell's right shoulder multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching

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61 Seeger, L.L., Gold, R.H., et al. (1988). "Shoulder Impingement Syndrome: MR Findings in 53 Shoulder." AJR, 150:343-347.
62 Murray, J-C. and Pelet, S. (2014). "Shoulder Impingement Syndrome Caused by a Voluminous Subdeltoid Lipoma." Case Reports In Orthopedics, Article ID 760219.3.
63 Escamilla, R.F., Hooks, T.R., Wilk, K.E. (2014). "Optimal management of shoulder impingement syndrome." Journal of Sports Medicine, 2014:5 13-24.
64 D'Alessandro, D.F., Fleischli, E., et al. (2000). "Superior Labral Lesions: Diagnosis and Management." Journal of Athletic Training 35(3): 286-292.
65 Payne, L. Z., (1994). "Tears of the Glenoid Labrum." Orthopaedic Review 577-583.
66 Park, J.H., Lee, Y.S., Wang, J.H., et al., (2008). "Outcome of Isolated SLAP Lesions and Analysis of the Results According to Injury Mechanisms." Knee Surg Sports Traumatol Arthrosc 16: 511-515.
67 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins
68 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.
69 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.
70 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.
71 Ivory, M.A., Furbish, C., et al. (2010). *Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions*. (No. 2010-01-0067). SAE Technical Paper.

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and lifting tasks are comparable to, or greater than that of the subject incident.[72,73,74,75] These data demonstrate that the shoulder forces and accelerations of the subject incident did not exceed Ms. Mitchell's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported right shoulder biomechanical failures of Ms. Mitchell cannot be made.

Personal Tolerance Values

According to the available documents, Ms. Mitchell is retired. Ms. Mitchell also testified to exercising for one hour five times per week including activities such as water aerobics, going on the treadmill and using the stationary bicycle. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Mitchell and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[76]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Mitchell's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Mitchell using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 9, 2014, Ms. Carolyn Mitchell was the seat-belted driver of a 2002 Ford Focus that was travelling northbound on N. Interstate Ave. in Portland, Oregon, when the subject Ford Focus was contacted in the rear at low speed by a 2006 Volvo XC90.
2. The severity of the subject incident was below 5.0 miles-per-hour with an average acceleration less than 1.5g.

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72 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

73 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics, 19: 586-594.

74 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

75 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

76 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)* (No. 960654). SAE Technical Paper Series.

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3. The acceleration experienced by Ms. Mitchell was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Mitchell's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mitchell's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mitchell's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mitchell's claimed shoulder biomechanical failures. As such, a causal relationship between the subject incident and the shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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EXHIBIT
Probst A
5-23-17 VMY

February 8, 2017

Claudia Shannon, Esquire
Law Offices of Sweeney & Dietzler
1191 Second Avenue
Suite 500
Seattle, WA 98101

Re: *Dominguez, Vicki v. Kenneth Schultz et al.*
File No.: AB346-042444
ARCCA Case No.: 2107-1112

Dear Ms. Shannon:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incidents in relation to the crash forces and the biomechanical failures claimed by Vicki Dominguez. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the available materials using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

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Incident Description:

Two incidents are addressed in this report.

The first incident occurred on February 14, 2013. The available documents indicate that Ms. Vicki Dominguez was the lap&shoulder belt restrained driver of a 1991 Mercedes-Benz 300 traveling northbound on Interstate 5 near South Boeing Access Road near Tukwila, Washington. Mr. Joseph Garinger was the driver of a 2005 Honda Civic traveling immediately behind the subject Mercedes. Ms. Danielle Johnson was the driver of a 1996 Pontiac Grand Prix immediately behind the incident Honda. Mr. Kenneth Schultz was the driver of a 2008 Ford E350 travelling immediately behind the incident Pontiac. The records indicate that the Mercedes, Honda, and Pontiac were all stopped for traffic when the front of the Ford contacted the rear of the Pontiac. Subsequently, the front of the Pontiac contacted the rear of the Honda, resulting in the front of the Honda contacting the rear of the Mercedes.

The second incident occurred on October 10, 2013. The available documents indicate that Ms. Vicki Dominguez was the lap&shoulder belt restrained driver of a 2001 Mercedes-Benz S500 traveling on northbound Interstate 5 near South Boeing Access Road near Tukwila, Washington. Mr. Stephan Orban was the driver of a 2006 Ford E250 traveling immediately behind the subject Mercedes. The records indicate that while the subject Mercedes was stopped for traffic, it was contacted in the rear by the front of the incident Ford.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Fourteen (14) color photographic reproductions of the incident 1996 Pontiac Grand Prix
- Twelve (12) color photographic reproductions of the incident 2005 Honda Civic
- Twelve (12) color photographic reproductions of the incident 2006 Ford E250
- Eleven (11) black and white photographic reproductions of the subject 2001 Mercedes-Benz S500
- Two (2) color photographic reproductions of the incident 2008 Ford E350
- Estimate of Repair for the subject 1991 Mercedes-Benz 300 [February 27, 2013]
- Estimate of Repair for the incident 2005 Honda Civic [February 20, 2013]
- Supplement of Record 2 with Summary for the incident 2008 Ford E350 [February 28, 2013]
- Estimate of repairs for the incident 1996 Pontiac Grand Prix [February 22, 2013]
- Estimate of repairs for the subject 2001 Mercedes-Benz S500 [October 11, 2013]
- Complaint for Injuries and Damages, *Vicki L. Dominguez v. Kenneth F. Schultz et al* [December 22, 2015]
- First Interrogatories and Requests for Production, *Vicki L. Dominguez v. Kenneth F. Schultz et al* [April 15, 2016]
- Medical Records pertaining to Vicki Dominguez
- VinLink data sheet for the subject 1991 Mercedes Benz 300
- Expert AutoStats data sheets for a 1991 Mercedes Benz 300

- VinLink data sheet for the subject 2001 Mercedes Benz S500
- Expert AutoStats data sheets for a 2001 Mercedes Benz S500
- VinLink data sheet for the incident 2005 Honda Civic
- Expert AutoStats data sheets for a 2005 Honda Civic
- VinLink data sheet for the incident 2008 Ford E350
- Expert AutoStats data sheets for a 2008 Ford E350
- Expert AutoStats data sheets for a 2006 Ford E250
- VinLink data sheet for the incident 1996 Pontiac Grand Prix
- Expert AutoStats data sheets for a 1996 Pontiac Grand Prix
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The methodology used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of these incidents, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Dominguez claims were caused by the subject incidents on February 14, 2013, and October 10, 2013;
2. Quantify the nature of the subject incidents in terms of the forces, accelerations, and changes in velocity (Delta-V) of the subject 1991 Mercedes-Benz 300 and 2001 Mercedes-Benz S500;
3. Determine Ms. Dominguez's kinematic responses within the vehicles as a result of the subject incidents;
4. Define the biomechanical failure mechanisms known to cause the claimed biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Dominguez's personal tolerances in the context of her pre-incident condition to determine, to a reasonable degree of scientific certainty, whether a causal relationship exists between the subject incidents and her claimed biomechanical failures.

If the subject incidents created the biomechanical failure mechanisms that generate the claimed biomechanical failures, a causal link between the biomechanical failures and the events cannot be ruled out. If, the subject incidents did not create the biomechanical failure mechanisms associated

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

with the claimed biomechanical failures, then a causal link to the subject incidents cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Dominguez attributes the following biomechanical failures as a result of the subject incidents:

- Cervical Spine
  - Sprain/strain
  - C2-3 disc protrusion
  - C5-6 disc bulge
- Lumbosacral Spine
  - Sprain/strain
  - L2-3, L3-4, L4-5, L5-S1 disc bulge
- Right Shoulder
  - Sprain/strain

Damage and Incident Severity:

The severity of the incidents was analyzed by using the photographic reproductions and repair estimates for the involved vehicles, in association with accepted scientific methodologies. [11,12]

First Incident, February 14, 2013

The repair estimate for the subject 1991 Mercedes-Benz 300 reported damage to the rear center bumper face bar molding, rear bumper retainer, rear bumper nuts, rear body panel, and rear bumper cover.

The repair estimate for the incident 2005 Honda Civic reported damage to the front bumper cover, front license plate frame, rear bumper cover, and rear bumper nameplate. The photographs depicted scrapes and a horizontal crack along the rear bumper cover, and a small dent to the front bumper cover (Figure 1). The front lower air guide was also cracked. There was no significant residual crush to either front or rear components.

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[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the incident 2005 Honda Civic

The repair estimate for the incident 1996 Pontiac Grand Prix reported damage to the rear body nameplate, rear bumper cover, rear body panel, both quarter panels, and right and left rear rails. The photographs depicted paint removal to the top of the rear bumper cover, and slight buckling of the left quarter panel (Figure 2). The front bumper was displaced relative to the left fender, the front license plate was deformed, and there was a gouge along the top of the front bumper near the license plate.

Figure 2: Reproductions of photographs of the incident 1996 Pontiac Grand Prix

The repair estimate for the incident 2008 Ford E350 reported damage to the front bumper, front bumper mount brackets, front reinforcement brackets, valence panel, license bracket, grille, upper support, grille mount panel, grille brackets, both headlamps and park lamps, right front tire, and required a frame measurement. The repair estimate also noted that the incident Ford was towed. The photographs show that the front bumper was crushed and displaced downward (Figure 3). The grille was cracked on the right side, and the left headlamp/park lamp was dislodged.

Figure 3: Reproductions of photographs of the incident 2008 Ford E350

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This fundamental law of physics dictates that a scientific analysis of the loads sustained by the incident Honda Civic can be used to resolve the loads sustained by the subject Mercedes-Benz 300. That is, the loads sustained by the incident Honda are equal and opposite to those of the subject Mercedes.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the vehicles' damage incurred in the tests. The impact damage to the incident Honda Civic, defined by the photographic reproductions and confirmed by the repair estimate, was used to perform a damage threshold speed change (Delta-V) analysis.[13] The IIHS tested an exemplar 2005 Honda Civic in a 5 mile-per-hour (mph) frontal impact into a flat barrier.[14] The tested Honda sustained damage to the front bumper cover, reinforcement, and absorber. The primary damage to the subject Honda was to the front bumper cover. Thus, because the Honda Civic in the IIHS frontal impact test sustained less damage than the incident Honda, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident. Accounting for restitution and utilizing the Conservation of Momentum law of physics, the Delta-V experienced by the subject Mercedes-Benz 300 was less than 4.5 mph, where Delta-V is defined as the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 4.5 mile-per-hour Delta-V is 1.4g.[15,16,17,18] By the laws of physics, therefore, the average acceleration experienced by the subject Mercedes-Benz in which Ms. Dominguez was seated was less than 1.4g.

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13 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA. Society of Automotive Engineers.

14 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2007 BMW 3 Series, July 2007

15 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration.* (No. 2000-01-0880). SAE Technical Paper.

16 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

17 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts.* (No. 970120). SAE Technical Paper.

18 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

Second Incident, October 10, 2013

The repair estimate for the subject 2001 Mercedes-Benz S500 reported damage to the rear bumper cover and center bumper impact strip. The photographs were of low quality, but did not depict significant crush to the rear of the subject vehicle (Figure 4).

Figure 4: Reproductions of photographs of the subject 2001 Mercedes-Benz S500

The photographs of the incident 2006 Ford E250 depicted a dent to the left side of the front bumper, and paint chips to the right side of the bumper (Figure 5). The front bumper remained in alignment with the grille and fenders. There was also damage to the left and right side panels which was unrelated to the subject incident.

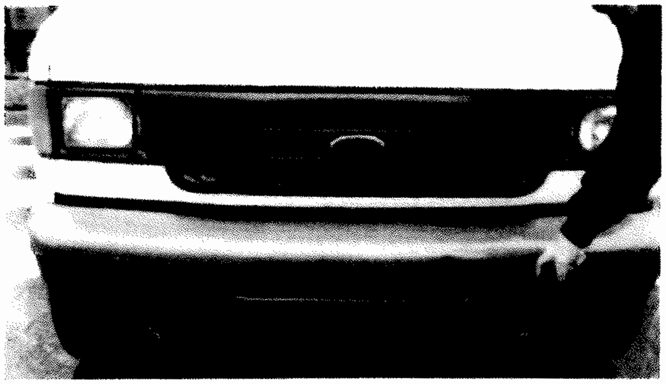

Figure 5: Reproductions of photographs of the incident 2006 Ford E250

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[19,20,21,22,23] Analyses of the photographs and geometric measurements of the incident 2006 Ford E250 revealed the damage caused by the subject incident. An energy crush analysis[24] indicates that a single 10 mph flat barrier impact to the front of an exemplar 2006 Ford E250 would result in significant and visibly noticeable crush across the entirety of the front structure of the vehicle, with a residual crush of 3.25 inches. Therefore, the energy crush analysis shows that significantly greater deformation would occur in a 10 mph Delta-V impact than what was caused by the subject incident.[25] Again, Delta-V is defined as the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity. Therefore, utilizing the Conservation of Momentum law of physics, the subject Mercedes experienced a Delta-V of significantly less than 12.5 mph.

Considering the similarities between the subject Mercedes-Benz vehicles in the two incidents, the Delta-V of the second incident involving the S500 is more consistent with a Delta-V comparable to that of the first incident. Therefore, the subject Mercedes-Benz S500 would have experienced a Delta-V of approximately 5 mph.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 12.5 mph Delta-V is 3.8g, and the average acceleration associated with a 5.0 mph Delta-V with the same acceleration pulse is 1.5g.[26,27,28,29] By the laws of physics, therefore, the average acceleration experienced by the subject Mercedes-Benz

19 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

20 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

21 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

22 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

23 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

24 EDCRASH, Engineering Dynamics Corp.

25 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

26 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

27 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

28 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

29 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

S500 in which Ms. Dominguez was seated was significantly less than 3.8g and more consistent with 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Dominguez experiences 1g of loading while in a sedentary state. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [30] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Therefore, Ms. Dominguez experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Dominguez's medical records indicated that she was 65 inches in height, weighed approximately 126 lbs, and was 63 years old at the time of the first incident and 64 at the time of the second. The laws of physics dictate that when the subject Mercedes-Benz 300 and the subject Mercedes-Benz S500 were contacted in the rear, the force would have pushed the vehicles forward, causing Ms. Dominguez's seat, which is attached to the vehicle, to also move forward relative to her body. This motion would result in Ms. Dominguez moving rearward relative to the interior of both vehicles, causing her to load into the seatback structures, and her torso and pelvis would settle into the seatback and seat bottom cushions. The available documents indicated Ms. Dominguez was wearing the available lap&shoulder belt restraint in both incidents. Any rebound would have been easily within the range of protection afforded by the available restraint system which would have coupled Ms. Dominguez's body to the seat structures. Therefore, the restraint provided by the seatback and seat belt system were such that any motion of Ms. Dominguez would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicles and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Dominguez in both incidents was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion of the affected joints, there is no biomechanical failure mechanism present to causally link her claimed biomechanical failures to the subject incident.[31,32]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two critical issues or questions:

1. Did the subject incident load (apply a force to) the body in a <u>manner</u> known to cause damage to a specific body part? That is, did the subject incident create a known biomechanical failure mechanism?

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[30] Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

[31] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

[32] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck.* (No. 710855). SAE Technical Paper.

2. If a biomechanical failure mechanism was present, did the subject incident load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the affected tissue, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be made.

Cervical Spine

A cervical X-ray performed February 20, 2013 reported no fracture or misalignment, but noted degenerative changes. A cervical MRI performed July 8, 2014 also reported degenerative changes, and a small disc protrusion at C2-3. Another MRI performed March 16, 2016 reported no significant degenerative disc disease changes from the prior imaging, but identified bulging at the C5-6 level.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to either subject incident. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, significant motion which produces stretching beyond its normal limits must occur to sustain a strain/sprain type biomechanical failure to any tissue. Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event in which forces are applied to the disc at magnitudes beyond its capacity or strength. Damage to the disc in the form of a bulge, protrusion, or herniation can then result. Based upon previous research, the accepted mechanism for acute intervertebral disc biomechanical failure involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[33]

In a rear impact that produces motion of the impacted vehicle, the vehicle would be pushed forward and, therefore, Ms. Dominguez would have moved rearward relative to the vehicle until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 1991 Mercedes-Benz 300 revealed that the nominal height of the front seatback and headrest with an unoccupied, uncompressed seat is fixed at 29 inches. Examination of an exemplar 2001 Mercedes-Benz S500 revealed that the nominal height of the front seatback with an unoccupied, uncompressed seat is 31.0 inches with the headrest in the full down position, and 34.0 inches with the headrest in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. An anthropometric regression analysis of Ms. Dominguez based on her height and weight revealed that she would have a normal seated height of 32.7 inches. Thus, in both incidents, the seatback and headrest support, in conjunction with the low vehicle accelerations, indicate that Ms. Dominguez's cervical spine would have undergone only a subtle degree of the characteristic response phases.[34] The load would have been applied predominantly horizontal to her cervical spine and would have

33 White III, A. A. and M. M. Panjabi (1990). *Clinical Biomechanics of the Spine*. Philadelphia, J.B. Lippincott Company.

34 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

minimized the relevant cervical loads.[35] Consequently, the cervical loads would have been within physiologic limits and Ms. Dominguez would not have been exposed to a cervical spine biomechanical failure mechanism during the either of the subject incidents.[36,37,38]

Several researchers have conducted rear impact studies with human volunteers at accelerations levels comparable to and even greater than that of the subject incident.[39,40,41,42,43] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. The resulting occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures, and none of the volunteers reported cervical biomechanical failures, even though several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. Previous research has reported that, even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[44] Additional studies conducted with cadaveric and anthropomorphic test devices (ATD, or test dummies) at severity levels comparable to that of the subject incident showed that the kinematics were inconsistent with the mechanism for cervical biomechanical failure and the experimentation failed to produce cervical trauma.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities, ranging from plopping into a chair to a simple head shake, can produce head and cervical accelerations comparable to or even greater than the subject incident. More dynamic activities, such as a vertical leap, produce even higher peak head accelerations of up to 4.75g. [45,46,47,48] Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or even

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35 Welch, T., Bridges. A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

36 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

37 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms. (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

38 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

39 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

40 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

41 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

42 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

43 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

44 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

45 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

46 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

47 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

48 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

greater than the accelerations associated with the subject incident.[49] The available documentation indicates that Ms. Dominguez was capable of performing regular daily activities.

Based upon the review of the available documentation for both incidents and the results cited in the technical literature as described above, the subject incidents created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As these crash events did not create forces that exceeded the limits of human tolerance, a causal link between the subject incidents and the claimed cervical spine biomechanical failures of Ms. Dominguez cannot be made.

Thoracic and Lumbosacral Spine

Lumbar and thoracic X-rays performed on February 20, 2013 reported no compression fractures. A lumbar MRI performed July 8, 2014 reported degenerative disc and facet disease, and disc bulging at the L2-3, L3-4, L4-5, and L5-S1 levels. Another MRI performed March 16, 2016 reported no significant changes from the prior imaging, but did report decreased disc height.

During both rear impact events, the thoracic and lumbosacral spine of Ms. Dominguez would have been well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Dominguez's thoracic and lumbosacral spine. The seatback would limit the range of movement to well within normal levels, and no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbosacral spine, and eliminating relative motion between the torso and the seatback structures. The lack of relative motion would result in a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbosacral spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at acceleration levels comparable to and even greater than those of the subject incidents.[50,51,52,53] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. The resulting kinematics were inconsistent with the mechanism for thoracic and lumbosacral biomechanical failure, and none of the participants reported any spinal trauma. West et al., subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities (BEV) ranging from approximately 2.5 mph to 8 mph.[54] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities

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49 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living.* (No. 2006-01-0247). SAE Technical Paper.

50 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

51 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

52 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

53 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration. Naval Biodynamics Laboratory, NBDL-86R006.

54 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5,* 22-26.

greater than the subject incident.[55,56] Therefore, Ms. Dominguez's thoracic and lumbosacral spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[57,58,59,60,61]

Multiple investigations have shown that apparently benign tasks, such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back, can generate loads that are comparable to or even greater than those resulting from the subject incident. [62,63,64,65] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step, to be comparable to or even greater than the subject incident.[66,67] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or even greater than those associated with the subject incident.[68] According to the available documents, Ms. Dominguez was capable of performing daily activities. A segmental analysis of Ms. Dominguez demonstrated that, as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or even greater than those during the subject incident.[69,70,71]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by both incidents were well within the normal range of motion associated with the thoracic and lumbosacral spine. Finally, the forces created by the subject incidents were well within the limits of human tolerance for the thoracic and

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55 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

56 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

57 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

58 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

59 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

60 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

61 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

62 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

63 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

64 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

65 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

66 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

67 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

68 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

69 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System. Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

70 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

71 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

lumbosacral spine and were within the range typically seen in normal, daily activities. As these crash events did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Dominguez, a causal link between the subject incidents and the claimed thoracic and lumbosacral biomechanical failures cannot be made.

Right Shoulder

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." Shoulder impingement syndrome refers to inflammation of the rotator cuff tendons and the bursa (bursitis) that surrounds these tendons. The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted, and repetitive microtrauma to the abducted shoulder joint.[72] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[15]

During both subject incidents, Ms. Dominguez's torso would have moved rearward relative to the vehicle's interior, and she would have been supported and constrained by the seatback.[73,74,75,76] The seatback would have distributed any loading across her entire back and shoulders. Any rebound would have been limited by the lap&shoulder belt she was wearing, which would have engaged Ms. Dominguez's bony left clavicle and pelvis. The restraint provided by the lap&shoulder belt and the seatback were such that any motion of Ms. Dominguez's right shoulder would have been limited to well within the range of normal physiological limits.

Common activities would directly load Ms. Dominguez's right shoulder multiple times to comparable or even greater loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities, such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks, are comparable to or even greater than those of the subject incidents.[77,78,79,80] These data demonstrate that the shoulder forces and accelerations of the subject incidents did not exceed Ms. Dominguez's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, both subject incidents created accelerations that were well within the limits of human

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72 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition. Lippincott Williams and Wilkins

73 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

74 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects.* (No. 2001-01-0168). SAE Technical Paper.

75 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

76 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions.* (No. 2010-01-0067). SAE Technical Paper.

77 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

78 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

79 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

80 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

tolerance and were comparable to a range typically seen during normal, daily activities. As these crash events did not create forces that exceeded the limits of human tolerance, a causal link between the subject incidents and the claimed right shoulder biomechanical failures of Ms. Dominguez cannot be made.

Personal Tolerance Values

The records indicated that Ms. Dominguez was employed by Nordstrom's, working 40 or more hours a week. She indicated that she was capable of performing lifting tasks at work, and was able to perform her daily activities without biomechanical failure. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Dominguez and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of both subject incidents. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Dominguez's claimed biomechanical failures and both subject incidents incorporated thorough analyses of both incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Dominguez using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On February 14, 2013, Ms. Vicki Dominguez was the lap&shoulder-belted driver of a 1991 Mercedes-Benz 300 that was stopped for traffic on northbound Interstate 5 near Tukwila, Washington. A 2008 Ford E350, driven by Mr. Kenneth Schultz, contacted the rear of a 1996 Pontiac Grand Prix driven by Danielle Johnson. The front of the Pontiac then contacted the rear of a 2005 Honda Civic driven by Joseph Garinger, which subsequently contacted the rear of the subject Mercedes.
2. On October 10, 2013, Ms. Vicki Dominguez was the lap&shoulder-belted driver of a 2001 Mercedes-Benz S500 that was stopped for traffic on northbound Interstate 5 near Tukwila, Washington, when the rear of her Mercedes was contacted by a 2006 Ford E250 driven by Stephan Orban.
3. The severity of the February subject incident was below 4.5 mph with an average acceleration less than 1.4g.
4. The severity of the October subject incident was significantly below 12.5 mph with an average acceleration significantly less than 3.8, and more comparable to 5 mph with an average acceleration of 1.5g.
5. The accelerations experienced by Ms. Dominguez during both incidents were within the limits of human tolerance and comparable to those experienced during various daily activities.

6. The forces applied to the subject vehicles during the subject incidents would tend to move Ms. Dominguez's body rearward toward the seatback structures. These motions would have been limited and well controlled by the seat structures and would be well within normal movement limits.
7. There is no biomechanical failure mechanism present in either subject incident to account for Ms. Dominguez's claimed cervical biomechanical failures. As such, a causal relationship between the subject incidents and the claimed cervical biomechanical failures cannot be made.
8. There is no biomechanical failure mechanism present in either subject incident to account for Ms. Dominguez's claimed thoracic and lumbosacral biomechanical failures. As such, a causal relationship between the subject incidents and the claimed thoracic and lumbosacral biomechanical failures cannot be made.
9. There is no biomechanical failure mechanism present in either subject incident to account for Ms. Dominguez's claimed right shoulder biomechanical failures. As such, a causal relationship between the subject incidents and the claimed right shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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March 10, 2017

Riley Lovejoy, Esquire
Law Offices of Sweeney & Dietzler
1001 4th Avenue
Suite 3300
Seattle, WA 98154

Re: *Ngo, Vuong v. Nudedien Adem Kamal & Davis Distributing Corp*
File No.: 446182116039
ARCCA Case No.: 2107-1231

Dear Mr. Lovejoy:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Vuong Ngo. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

According to the available documents, on November 20, 2015, Mr. Vuong Ngo was the driver of a 2000 Toyota Camry traveling on 1st Ave. in Seattle, Washington. A commercial truck was travelling behind the subject Toyota and in the lane directly to the left. While merging to the right, the commercial truck contacted the subject Toyota on the left rear side. Subsequently, the subject Toyota was pushed forward and made contact with the rear of a 2010 Subaru Forester.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Four (4) color photographic reproductions of the subject incident scene
- One (1) color photographic reproduction of the incident 2010 Subaru Forester
- Defendant's First Interrogatories, Vuong Ngo vs. Nurdedien Adem Kamal & Davidson Distributing Corp [May 20, 2016]
- Recorded statement from Vuong Ngo [December 7, 2015]
- Deposition transcript from Vuong Ngo [October 21, 2016]
- Expert AutoStats data sheets for a 2000 Toyota Camry
- VinLink data sheet for the incident 2010 Subaru Forester
- Expert AutoStats data sheets for a 2010 Subaru Forester
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Mr. Ngo claims were caused by the subject incident on November 20, 2015;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2000 Toyota Camry;
3. Determine Mr. Ngo's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

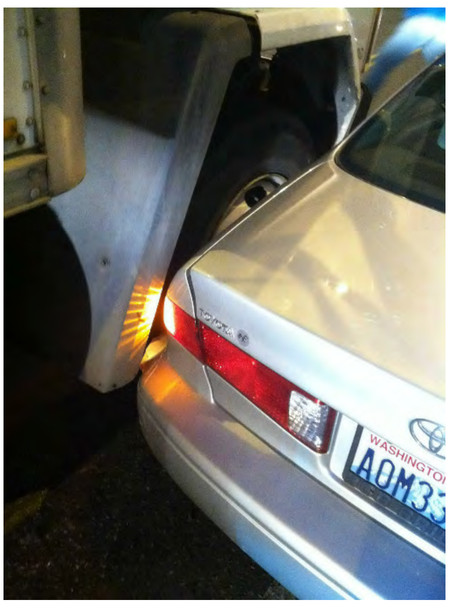
5. Evaluate Mr. Ngo's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

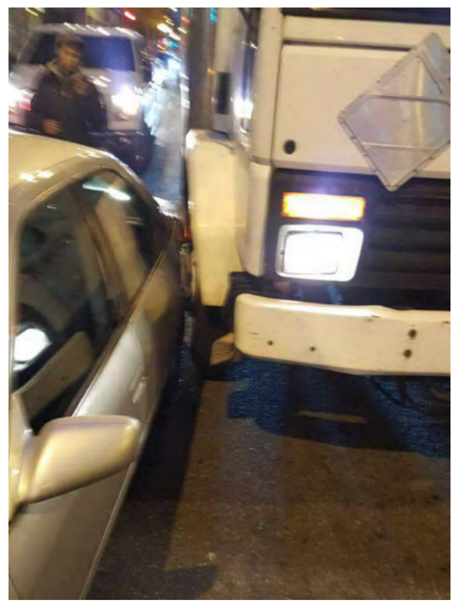
If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the subject 2000 Toyota Corolla and the subject incident scene in association with accepted scientific methodologies.[11,12]

The photographs of the subject Toyota Corolla depicted residual crush to the left rear quarter panel and left corner of the rear bumper cover (Figure 1). The photographs of the incident Subaru depicted small dents to the center of the rear bumper cover, consistent with license plate bolt contact and no residual crush (Figure 2).





[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

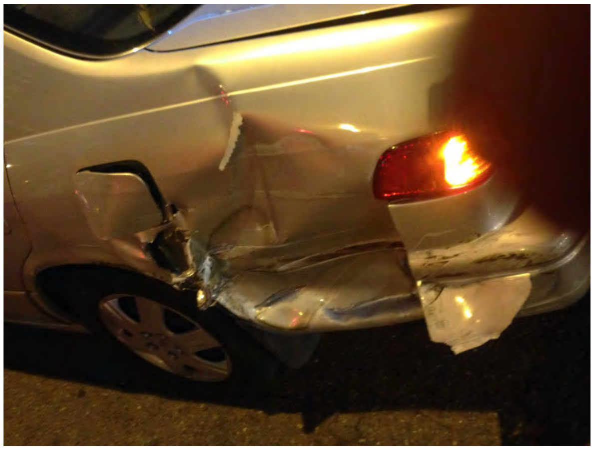


Figure 1: Reproductions of photographs of the subject 2000 Toyota Corolla

Figure 2: Reproduction of photograph of the incident 2010 Subaru Forester

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements of the subject 2000 Toyota Corolla revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 mile per hour flat barrier impact to the rear of an exemplar Toyota Corolla would result in significant and visibly noticeable crush across 2 inches of the left corner of the subject Toyota's rear structure, with a residual crush of 45 inches. As a point of reference, the distance between the rear bumper and the rear axle is 41 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

crush to the rear left side of the subject Toyota Corolla indicates a collision resulting in a Delta-V significantly below 10 miles per hour. [20,21,22,23,24,25]

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour impact is 3.0g.[26,27,28,29] By the laws of physics, the average acceleration experienced by the subject Toyota Corolla in which Mr. Ngo was seated was significantly less than 3.0g.

Further evaluating the frontal impact, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Toyota Corolla, defined by the photographic reproductions, was used to perform a damage threshold speed change analysis.[30] The IIHS tested an exemplar Toyota Corolla in a 5 mile-per-hour front impact into a rigid barrier.[31] The test Toyota sustained no damage. The photographic reproductions of the subject Toyota depicted no damage to the front structures. According to the IIHS protocol definitions of damage, the subject incident damage to the subject Toyota would be classified as no damage. [32] Thus, because the test Toyota in the IIHS frontal impact test sustained similar damage, the severity and energy transfer of the IIHS impact is similar compared to the severity of the subject incident and places the Toyota Corolla speed at the test speed of 5 miles-per-hour. Accounting for restitution, the subject Toyota experienced a Delta-V of 6.5 miles-per-hour.[33,34]

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20 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2010 Honda CR-V into 2010 Honda Civic, December 2010.

21 Campbell, K.L., (1974) Energy Basis for Collision Severity, (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

22 Day, T.D. and Siddall, D.E., (1996) Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment, (SAE 960891). Warrendale, PA, Society of Automotive Engineers.

23 Day, T.D. and Hargens, R.L., (1985) Differences Between EDCRASH and CRASH3, (SAE 850253). Warrendale, PA, Society of Automotive Engineers.

24 Day, T.D. and Hargens, R.L., (1989) Further Validation of EDCRASH Using the RICSAC Staged Collisions, (SAE 890740). Warrendale, PA, Society of Automotive Engineers.

25 Day, T.D. and Hargens, R.L., (1987) An Overview of the Way EDCRASH Computes Delta-V, (SAE 870045). Warrendale, PA, Society of Automotive Engineers.

26 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

27 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

28 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

29 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

30 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

31 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 1998 Toyota Corolla, November 1997.

32 Insurance Institute for Highway Safety Low-Speed Crash Test Protocol. October 2001.

33 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

34 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.5 mile-per-hour impact is 2.0g.[35,36,37,38] By the laws of physics, the average acceleration experienced by the subject Toyota Corolla in which Mr. Ngo was seated was 2.0g.

The acceleration experienced due to gravity is 1g. This means that Mr. Ngo experiences 1g of loading while in a sedentary state. Therefore, Mr. Ngo experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[39] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

The laws of physics dictate that when the subject Toyota was contacted in the left rear corner, it would have been pushed forward causing the seats to move forward relative to an occupant in the vehicle. This motion would result in the occupant moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. The torso and pelvis would settle back into the seatback and seat bottom cushions.

Upon impact between the subject Toyota and incident Subaru, the laws of physics dictate the Toyota would have been decelerated longitudinally. Had the forces generated during this interaction been sufficient to overcome the muscle reaction forces, a human body would have moved primarily forward relative to the Toyota's interior. The three-point restraint would have locked when the vehicle accelerations exceeded 0.7g.[40] The seat belt would support and limit forward body excursion. Friction generated at the seat bottom, as well as the passive muscle resistance of the arms, would have acted in conjunction with the three-point restraint to limit body motion. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of an occupant would have been limited to well within the range of normal physiological limits.

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35 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

36 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

37 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

38 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

39 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

40 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[41,42,43,44] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[45] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[46,47]

Studies by Rohlmann et al.[48,49,50] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[51] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[52]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident.

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[41] Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

[42] Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

[43] Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

[44] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[45] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

[46] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[47] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

[48] Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

[49] Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

[50] Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

[51] Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

[52] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 20, 2015, Mr. Vuong Ngo was the driver of a 2000 Toyota Corolla stopped for traffic on 1st Ave. in Seattle, Washington, when contact occurred between the left rear side of the Toyota and the front right corner of a commercial truck. Subsequently, the subject Toyota was pushed forward and made contact with the rear of a 2010 Subaru Forester.
2. The severity of the rear impact during the subject incident was significantly below 10 miles-per-hour with an average acceleration less than 3.0g.
3. The severity of the frontal impact during the subject incident was 6.5 miles-per-hour with an average acceleration of 2.0g.
4. Had there been enough energy transferred to cause any motion, the Toyota Corolla would have been accelerated and pushed forward, coupling an occupant's motion to the vehicle, and causing the body to load into the seat and seatback. The forces applied to the subject vehicle during the subsequent frontal impact would tend to move an occupant's body forward relative to the vehicle's interior. These motions would have been limited and well controlled by the seat structures and available three point restraint system. All motions would be well within normal movement limits.
5. The acceleration experienced by Mr. Vuong Ngo was within the limits of human tolerance and comparable to that experienced during various daily activities.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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May 12, 2017

Charlene McCarthy, Esquire
Law Offices of Kathryn Reynolds Morton
650 NE Holladay Street
PO Box 4400
Portland, OR 97208-4400

Re: *LaParne, Judith v. Alysha Coca*
File No.: 029831505
ARCCA Case No.: 2107-1200

Dear Ms. McCarthy:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Judith LaParne. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

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3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

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5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

ARCCA INCORPORATED

Incident Description:

According to the available documents, on May 26, 2014, Ms. Judith LaParne was the seat-belted driver of a 1999 GMC Suburban traveling on 185th Ave. in Hillsboro, Oregon. Ms. Alysha Coca was the driver of a 2000 Honda Accord traveling immediately behind the subject GMC Suburban. While stopped in traffic, contact was made between the rear of the subject GMC Suburban and the front of the incident Honda Accord.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Three (3) color photographic reproductions of the subject 1999 GMC Suburban
- One (1) color photographic reproduction of the incident 2000 Honda Accord
- Preliminary Estimate for subject 1999 GMC Suburban [June 2, 2014]
- Preliminary Estimate for subject 1999 GMC Suburban [August 25, 2014]
- Estimate for the subject 1999 GMC Suburban [June 2, 2014]
- Medical Records pertaining to Judith LaParne
- VinLink data sheet for the subject 1999 GMC Suburban
- Expert AutoStats data sheets for a 1999 GMC Suburban
- VinLink data sheet for the incident 2000 Honda Accord
- Expert AutoStats data sheets for a 2000 Honda Accord
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. LaParne claims were caused by the subject incident on May 26, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1999 GMC Suburban;
3. Determine Ms. LaParne's kinematic responses within the vehicle as a result of the subject incident;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. LaParne's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. LaParne attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar and Sacral Spine
  - Sprain/strain
- Left Foot
  - Pain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 1999 GMC Suburban and the photographic reproductions of the incident 2000 Honda Accord in association with accepted scientific methodologies. [11,12]

The repair estimate for the subject 1999 GMC Suburban reported damage to the tailgate shell, rear bumper step assembly, left/right rear bumper step pad, and rear bumper step pad. This is depicted in the reviewed photographs (Figure 1). There is no residual crush to the rear bumper structures.

The photographs of the incident Honda Accord depicted a gap between the hood and the fender, as well as a gap between the front bumper cover and the headlamp (Figure 2).

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[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 1999 GMC Suburban

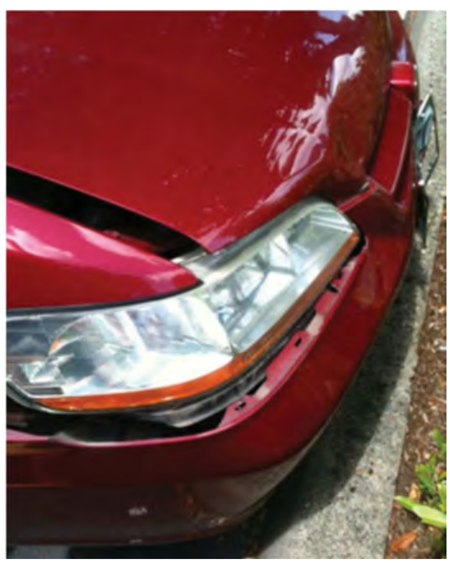

Figure 2: Reproduction of photograph of the incident 2000 Honda Accord

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Honda Accord can be used to resolve the loads sustained by the subject GMC Suburban. That is, the loads sustained by the incident Honda are equal and opposite to those of the subject GMC.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photographs and geometric measurements of the incident 2000 Honda Accord revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 mile per hour flat barrier impact to the front of an exemplar Honda Accord would result in significant and visibly noticeable crush across the entirety of the subject Honda's front structure, with a residual crush of 2.75 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural crush to the entire front of the incident Honda Accord indicates a collision resulting in a Delta-V significantly below 10 miles per hour. Using the conservation of momentum, the Delta-V for the subject GMC Suburban is 6.3 miles-per-hour

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.3 mile-per-hour impact is 3.0g.[20,21,22,23] By the laws of physics, the average acceleration experienced by the subject GMC Suburban in which Ms. LaParne was seated was significantly less than 1.9g. This analysis is consistent with the IIHS low-speed crash test for a comparable vehicle by the same manufacturer. [24]

The acceleration experienced due to gravity is 1g. This means that Ms. LaParne experiences 1g of loading while in a sedentary state. Therefore, Ms. LaParne experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [25] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

20 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

21 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

22 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

23 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

24 Insurance Institute for Highway Safety Bumper Evaluation Crash Test Report. 1998 Honda Accord, March 1998.

25 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Kinematic Analysis:

Ms. LaParne's medical records indicated she was 68 inches in height, weighed approximately 192 lbs., and was 58 years old at the time of the subject incident. The available documents indicated that Ms. LaParne saw the impact coming and was braced for the impact. The documents also indicated that she facing forward and slightly to the right, looking into the rear view mirror, with her foot on the brake prior to impact.

The laws of physics dictate that when the subject GMC Suburban was contacted in the rear, it would have been pushed forward causing Ms. LaParne's seat to move forward relative to her body. This motion would result in Ms. LaParne moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. LaParne's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. LaParne was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. LaParne's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. LaParne would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. LaParne was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[26,27]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

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26 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

27 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the GMC Suburban would be pushed forward and Ms. LaParne would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 1999 GMC Suburban revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 28.0 inches in the full down position, and 32.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. LaParne revealed she would have a normal seated height of 34.2 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. LaParne's cervical spine would have undergone only a subtle degree of the characteristic response phases.[28] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[29] The cervical loads were within physiologic limits and Ms. LaParne would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[30,31,32]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[33,34,35,36,37] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[38] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

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28 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

29 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

30 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

31 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

32 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

33 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

34 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

35 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

36 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

37 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

38 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [39,40,41,42] The available documents reported Ms. LaParne was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[43]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. LaParne cannot be made.

<u>Thoracic, Lumbar, and Sacral Spine</u>

The available medical records indicated that X-rays of the cervical, thoracic, and lumbar spines were taken on July 28, 2014 and the results showed no fracture.

During an event such as the subject incident, the thoracic, lumbar, and sacral spine of Ms. LaParne is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. LaParne's thoracic, lumbar, and sacral spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic, lumbar, and sacral spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic, lumbar, and sacral spine; thus, it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[44,45,46,47] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic, lumbar,

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39 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

40 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

41 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

42 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

43 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

44 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

45 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

46 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

47 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

and sacral biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[48] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[49,50] Ms. LaParne's thoracic, lumbar, and sacral spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[51,52,53,54,55]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[56,57,58,59] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[60,61] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[62] According to the available documents, Ms. LaParne was capable of performing daily activities. A segmental analysis of Ms. LaParne

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48 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

49 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

50 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

51 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

52 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

53 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

54 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

55 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

56 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

57 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

58 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

59 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

60 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

61 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Thoracic and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

62 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[63,64,65]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic, lumbar, and sacral spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic, lumbar, and sacral spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. LaParne, a causal link between the subject incident and claimed thoracic, lumbar, and sacral biomechanical failures cannot be made.

Left Foot

The medical records indicated that an MRI of the left foot was taken on September 25, 2014 and the results showed mild degenerative changes. The records also indicated Ms. LaParne underwent left foot surgery on September 26, 2014 and the procedure included 2nd and 3rd metatarsal osteotomies.

Ms. LaParne's body would have moved rearward relative to the interior of the subject GMC. This motion would have moved their feet and ankles away from the floorboard, gas/brake pedals, and other frontal components. Given the low accelerations associated with this incident and direction of impact, little to no forward motion would be expected. However, had significant forward motion occurred, the three-point restraint would have locked during the subject incident, which would have limited any forward excursion of their torsos, including their feet and ankles. These actions do not create the biomechanical failure mechanisms required for a left foot biomechanical failure. The loading and kinematics of Ms. LaParne's feet were well within the limits of human tolerance and physiological motion.

[63] Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.
[64] Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.
[65] Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

Daily activities and occurrences such as walking, stumbling, single leg hopping, and jumping have been shown to have comparable and greater impact forces on the body. [66,67,68,69,70,71,72,73,74,75,76,77] These actions would apply direct and repetitive loads to Ms. LaParne's feet and ankles of comparable or greater magnitude than she was exposed to during the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the knees. Finally, the forces created by the incident were well within the limits of human tolerance for the feet and ankle, and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. LaParne, a causal link between the subject incident and claimed foot biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Ms. LaParne was able to perform normal activities of daily living. These activities can produce greater movement, or stretch, to the soft tissues of Ms. LaParne and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[78]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. LaParne's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding

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66 Keller, T.S., et al., (1996) "Relationship between vertical ground reaction force and speed during walking, slow jogging and running." *Clinical Biomechanics,* 11(5): 253-259.

67 Gottschall, J.S., Kram, R., (2005) "Ground reaction forces during downhill and uphill running." *Journal of Biomechanics,* 38: 445-452.

68 Bergmann, G., Graichen, F., Rohlmann, A., (2003) "Hip joint contact forces during stumbling." *Langenbecks Arch Surg,* 389:53-59.

69 Lindenberg, K.M., Garcia, C.R., (2013) "The influence of heel height on vertical ground reaction force during landing tasks in recreationally active and athletic collegiate females." *The International Journal of Sports Physical Therapy,* 8(1): 1-8.

70 Veilleux, L.N., Rauch, F., Lemay, M., Ballaz, L., (2012) "Agreement between vertical ground reaction force and ground reaction force vector in five common clinical tests." *J Musculoskeletal Neuronal Interact,* 12(4):219-223.

71 Kluitenberg, B., et al., (2012) "Comparison of vertical ground reaction forces during overground and treadmill running. A validation study." *BMC Musculoskeletal Disorders,* 1-8.

72 Schipplein, O.D, Andriacchi, T.P. (1991) "Interaction Between Active and Passive Knee Stabilizers During Level Walking." *Journal of Orthopaedic Research* 9: 113-119.

73 Nordin M. and Frankel V.H. (1989).Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

74 Taylor, W.R., Heller, M.O. et al. (2004). "Tibio-Femoral Loading During Human Gait and Stair Climbing." *Journal of Orthopaedic Research* 22: 625-632.

75 Devita, P. and Hortobagyi, T. (2003). "Obesity is Not Associated with Increased Knee Joint Torque and Power During Level Walking." *Journal of Biomechanics* 36: 1355-1362.

76 Gushue, D.L., Houck, J., Lerner, A.L. (2005). "Effects of Childhood Obesity on Three-Dimensional Knee Joint Biomechanics During Walking." *Journal of Pediatric Orthopedics* 25(6): 763-768.

77 Kaufman, K.R., Hughes, C., et al. (2001). "Gait Characteristics of Patients with Knee Osteoarthritis." *Journal of Biomechanics* 34: 907-915.

78 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

of the unique personal tolerance level of Ms. LaParne using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 26, 2014, Ms. Judith LaParne was the seat-belted driver of a 1999 GMC Suburban that was stopped on 185th Ave. in Hillsboro, OR, when low speed contact occurred between the rear of the subject GMC Suburban and the front of a 2000 Honda Accord.
2. The severity of the subject incident was below 6.3 miles-per-hour with an average acceleration less than 1.9g.
3. The acceleration experienced by Ms. LaParne was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. LaParne's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. LaParne's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. LaParne's claimed thoracic, lumbar, and sacral biomechanical failures. As such, a causal relationship between the subject incident and the thoracic, lumbar, and sacral biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. LaParne's claimed left foot biomechanical failures. As such, a causal relationship between the subject incident and the left foot biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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June 12, 2017

Andrew D. Le, Esquire
Law Offices of Sweeney & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Butchart, Debbie Joe v. Ronald Coulter*
File No.: 4293 7763 5036
ARCCA Case No.: 2107-1267

Dear Mr. Le:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Debbie Butchart. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on August 11, 2013, Ms. Debbie Butchart was the seat-belted driver of a 2008 Saturn Astra traveling in Cle Elum, Washington. Mr. Ronald Coulter was the driver of a 2004 Chevrolet Trailblazer was traveling immediately behind the subject Saturn. As the subject Saturn stopped at a traffic light, contact was made between the rear of the Saturn and the front of the incident Chevrolet. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Four (4) color photographic reproductions of the subject 2008 Saturn Astra
- Three (3) color photographic reproductions of the incident 2004 Chevrolet Trailblazer
- Estimate of Record for the subject 2008 Saturn Astra [August 22, 2013]
- Supplement of Record 1 for the subject 2008 Saturn Astra [September 6, 2013]
- Deposition transcript from Debbie Butchart [October 18, 2016]
- VinLink data sheet for the subject 2008 Saturn Astra
- Expert AutoStats data sheets for a 2008 Saturn Astra
- VinLink data sheet for the incident 2004 Chevrolet Trailblazer
- Expert AutoStats data sheets for a 2004 Chevrolet Trailblazer
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2008 Saturn Astra and photographic reproductions of the incident 2004 Chevrolet Trailblazer in association with accepted scientific methodologies. [6,7]

The repair documentation for the subject Saturn reported the damage to the rear bumper cover, impact bar, and left outer support (Figure 1). The photographs depicted no residual crush to the rear bumper structures.

The photographs of the incident 2004 Chevrolet Trailblazer depicted no residual crush to the front bumper structures (Figure 2).

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6 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

7 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Photographic reproductions of the subject 2008 Saturn Astra

Figure 2: Photographic reproductions of the incident 2004 Chevrolet Trailblazer

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Saturn Astra, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[8] The IIHS tested a 2008 Saturn Astra in a 6.2 mile-per-hour front impact into a rigid barrier.[9] The test Saturn sustained damage to the inner cover support, lid deck molding, rear body panel, rear bumper, rear bumper cover, absorber, left/right rear bumper mounting bracket, and required a rear body panel pull (Figure 3). The primary damage to the subject incident Saturn Astra was to the rear bumper cover, impact bar, and left outer support. Thus, because the test Saturn in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident and places the Saturn Astra speed below the test speed of 6.2 miles-per-hour. Accounting for restitution, the subject Saturn experienced a Delta-V below 8.0 miles-per-hour.[10,11]

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8 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

9 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2008 Saturn Astra, September 2008.

10 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

11 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

Figure 3. Photographic reproductions of the 2008 Saturn Astra in the IIHS rear impact test

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with an 8.0 mile-per-hour impact is 2.4g.[12,13,14,15] By the laws of physics, the average acceleration experienced during the rear impact by the subject Saturn Astra in which Ms. Butchart was seated was significantly less than 2.4g.

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that a person experiences 1g of loading while in a sedentary state. Therefore, Ms. Butchart experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [16] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

The laws of physics dictate that when the subject Saturn was contacted in the rear, it would have been pushed forward causing the seats to move forward relative to an occupant in the vehicle. This motion would result in the occupant moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. The torso and pelvis would settle back into the seatback and seat bottom cushions.

12 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

13 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

14 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

15 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

16 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[17,18,19,20] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[21] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[22,23]

Studies by Rohlmann et al.[24,25,26] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[27] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[28]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident.

---

17 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

18 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

19 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

20 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

21 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

22 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

23 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

24 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

25 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

26 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

27 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

28 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

ARCCA INCORPORATED

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On August 11, 2013, Ms. Debbie Butchart was the seat-belted driver of a 2008 Saturn Astra stopped at a traffic signal in Cle Elum, Washington, when contact occurred between the rear of the Saturn and the front of a 2004 Chevrolet Trailblazer at a low speed.
2. The severity of the rear impact during the subject incident was significantly below 8.0 miles-per-hour with an average acceleration less than 2.4g.
3. Had there been enough energy transferred to cause any motion, the Saturn Astra would have been accelerated and pushed forward, coupling an occupant's motion to the vehicle, and causing the body to load into the seat and seatback.
4. The acceleration experienced by Ms. Butchart was within the limits of human tolerance and comparable to that experienced during various daily activities.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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June 19, 2017

Albert Kang, Esquire
Law Offices of Sweeney & Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Rodrigues-Ramirez, Maria v. Chelsea Shalloway*
File No.: 026737980-03
ARCCA Case No.: 2107-1296

Dear Mr. Kang:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Maria Rodrigues-Ramirez. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

---

1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on April 27, 2013, Mr. Maria Rodrigues-Ramirez was the seat-belted driver of a 2002 Dodge Grand Caravan traveling on southbound Interstate 405 near Bellevue, Washington. Ms. Angel Yuzney, Ms. Peloma Botello, Ms. Rosa Botello, Ms. Alexa Botello, and Ms. Yunnen Botello were passengers of the subject Dodge. Ms. Chelsea Rall (Shalloway) was the driver of a 2001 Volkswagen Jetta that was also traveling on southbound Interstate 405 Mr. Steven Shalloway was the front passenger of the incident Jetta. According to the police report, as the subject Dodge was changing lanes to the right, contact occurred between the right rear of the subject Dodge and the left front of the incident Volkswagen.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. E243233*
- One (1) color photographic reproduction of the subject 2002 Dodge Grand Caravan
- Two (2) color photographic reproductions of the incident 2001 Volkswagen Jetta
- Estimate for repairs of the subject 2002 Dodge Grand Caravan [May 6, 2013]
- Collision Reconstruction and Forensic Analysis by Robert Stearns [November 17, 2015]
- Independent Medical Examination of Maria Rodrigues-Ramirez [April 25, 2017]
- Medical Records Review for Maria Rodriguez-Ramirez [December 6, 2016]
- VinLink data sheet for the subject 2002 Dodge Grand Caravan
- Expert AutoStats data sheets for a 2002 Dodge Grand Caravan
- VinLink data sheet for the subject 2001 Volkswagen Jetta
- Expert AutoStats data sheets for a 2001 Volkswagen Jetta
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair documents for the subject 2002 Dodge Grand Caravan, and photographic reproductions of the incident 2001 Volkswagen Jetta, in association with accepted scientific methodologies. [6,7]

The repair estimate for the subject Dodge Grand Caravan reported damage to the rear bumper cover. The photograph showed only a limited view of the vehicle, depicting a small scrape on the rear bumper cover below the license plate.

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6 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

7 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproduction of photograph of the subject 2002 Dodge Grand Caravan

The photographs of the 2001 Volkswagen Jetta depicted scrapes along the left side of the front bumper cover, but no significant crush (Figure 2).

Figure 2: Reproductions of photographs of the incident 2001 Volkswagen Jetta

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Grand Caravan, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[8] The IIHS tested a 2001 Dodge Grand Caravan, the same production year and series as a 2002 Dodge Grand Caravan, in a 5 mile-per-hour rear impact into a flat barrier.[9] The test Dodge sustained damage to the rear bumper reinforcement, bumper mounting brackets, rear body panel, and tailgate. The primary damage to the subject Dodge was to the rear bumper cover. Thus, because the test Grand Caravan in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident. Accounting for restitution, the subject Dodge Grand Caravan experienced a

8 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

9 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2001 Dodge Grand Caravan, January 2001.

Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of less than 6.4 miles-per-hour. [10]

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.4 mile-per-hour Delta-V is 1.9g.[11,12,13,14] By the laws of physics, the average acceleration experienced by the subject Dodge Grand Caravan in which Ms. Rodrigues-Ramirez was seated was less than 1.9g.

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that a person experiences 1g of loading while in a sedentary state. Therefore, Ms. Rodrigues-Ramirez experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [15] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Rodrigues-Ramirez's medical records indicated she was 62 inches in height, weighed approximately 153 lbs., and was 37 years old at the time of the subject incident. Ms. Rodrigues-Ramirez indicated she was facing forward and was unaware of the oncoming impact. She stated that her body jerked back and forth, and that she had her arms on the steering wheel.

The laws of physics dictate that when the subject Dodge was contacted in the rear, it would have been pushed forward causing Ms. Rodrigues-Ramirez's seat to move forward relative to her body. This motion would result in Ms. Rodrigues-Ramirez moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Rodrigues-Ramirez's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Rodrigues-Ramirez was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Rodrigues-Ramirez's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Rodrigues-Ramirez would have been limited to well within the range of normal physiological limits. Specifically, the records indicate Ms. Rodrigues-Ramirez had four children, was capable of using the treadmill, and played basketball with her friends. These and other activities of daily living would directly load Ms. Rodrigues-Ramirez's body to comparable or greater loads than those experienced during the subject incident.

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10 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

11 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

12 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

13 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

14 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

15 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[16,17,18,19] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[20] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[21,22]

Studies by Rohlmann et al.[23,24,25] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes, and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[26] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[27]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident.

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16 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

17 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

18 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

19 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

20 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

21 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

22 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

23 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

24 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

25 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

26 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

27 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On April 27, 2013, Ms. Maria Rodrigues-Ramirez was the seat-belted driver of a 2002 Dodge Grand Caravan traveling southbound on Interstate 405 near Bellevue, Washington, when contact occurred between the right rear of the Dodge Grand Caravan and the left front of a 2001 Volkswagen Jetta at a low speed.
2. The severity of the rear impact during the subject incident was below 6.4 miles-per-hour with an average acceleration less than 1.9g.
3. The acceleration experienced by Ms. Rodrigues-Ramirez was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. Had there been enough energy transferred to cause any motion, the Grand Caravan would have been accelerated and pushed forward, coupling an occupant's motion to the vehicle, and causing the body to load into the seat and seatback. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. The acceleration experienced by Ms. Rodrigues-Ramirez was within the limits of human tolerance and comparable to that experienced during various daily activities.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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June 23, 2017

Marvin Lee, Esquire
Hollenbeck, Lancaster, Miller & Andrews
15500 SE 30th Place
Suite 201
Bellevue, WA 98007

Re: *Osborne, Dean v. Dynamic Duo Delivery Service*
Claim No.: 3007025900
ARCCA Case No.: 2723-160

Dear Mr. Lee:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Dean Osborne. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from

---

1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

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inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Incident Description:

According to the testimony and other available documents, on August 18, 2016, Mr. Dean Osborne was the seat belted driver of a 2008 Ford F150 traveling westbound on Highway 18 in Auburn, Washington. Mr. Maurice Green was the driver of a 2004 UD2600 box truck traveling immediately behind the subject Ford. As the subject Ford changed lanes to the right, traffic slowed to a stop. As the incident box truck attempted to pass the subject Ford, contact occurred between the front right corner of the box on the box truck and the left rear of the subject Ford (Figure 1).

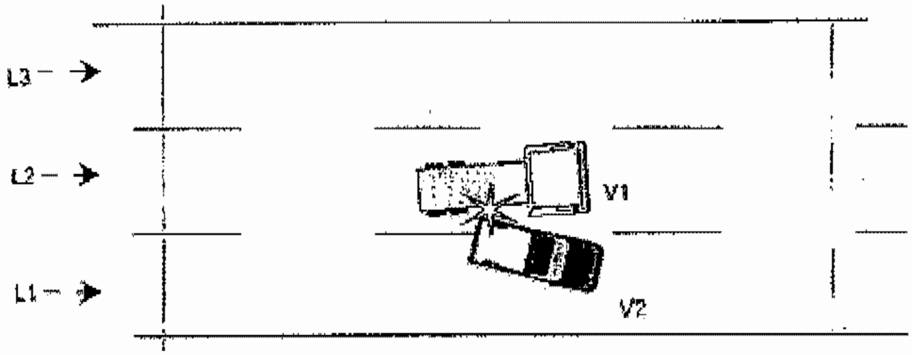

Figure 1: Incident diagram from the Police Traffic Collision Report. V1 – 2004 UD2600, V2 – 2008 Ford F150

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. E575758* [August 18, 2016]
- Vehicle inspection performed by Bradley Probst [February 14, 2017]
- Sixteen (16) color photographic reproductions of the subject 2008 Ford F150
- Two (2) color photographic reproductions of the incident 2004 UD2600 PKA 213
- Supplement of Record 1 Summary for the subject 2008 Ford F150 [November 1, 2016]
- VinLink data sheet for the subject 2008 Ford F150
- Expert AutoStats data sheets for a 2008 Ford F150
- VinLink data sheet for the incident 2004 UD2600 PKA 213
- Publicly available literature, including, but not limited to, the documents cited within the report, learned treatises, text books, and scientific standards

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair documents of the subject 2008 Ford F150, and photographs of the incident 2004 UD2600 box truck in association with accepted scientific methodologies.[6,7]

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6 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

7 Campbell, K.L. (1974). Energy Basis for Collision Severity (SAE 740565). Warrendale, PA, Society of Automotive Engineers.

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The repair estimate for the subject Ford F150 reported damage to the rear bumper and step pad, left tail lamp assembly, left decal, left side panel, left upper molding of bed, and left stone guard. The photographs depicted crush to the left corner of the left side panel, cracking to the left tail light, and scrapes to the left side of the rear bumper (Figure 2).

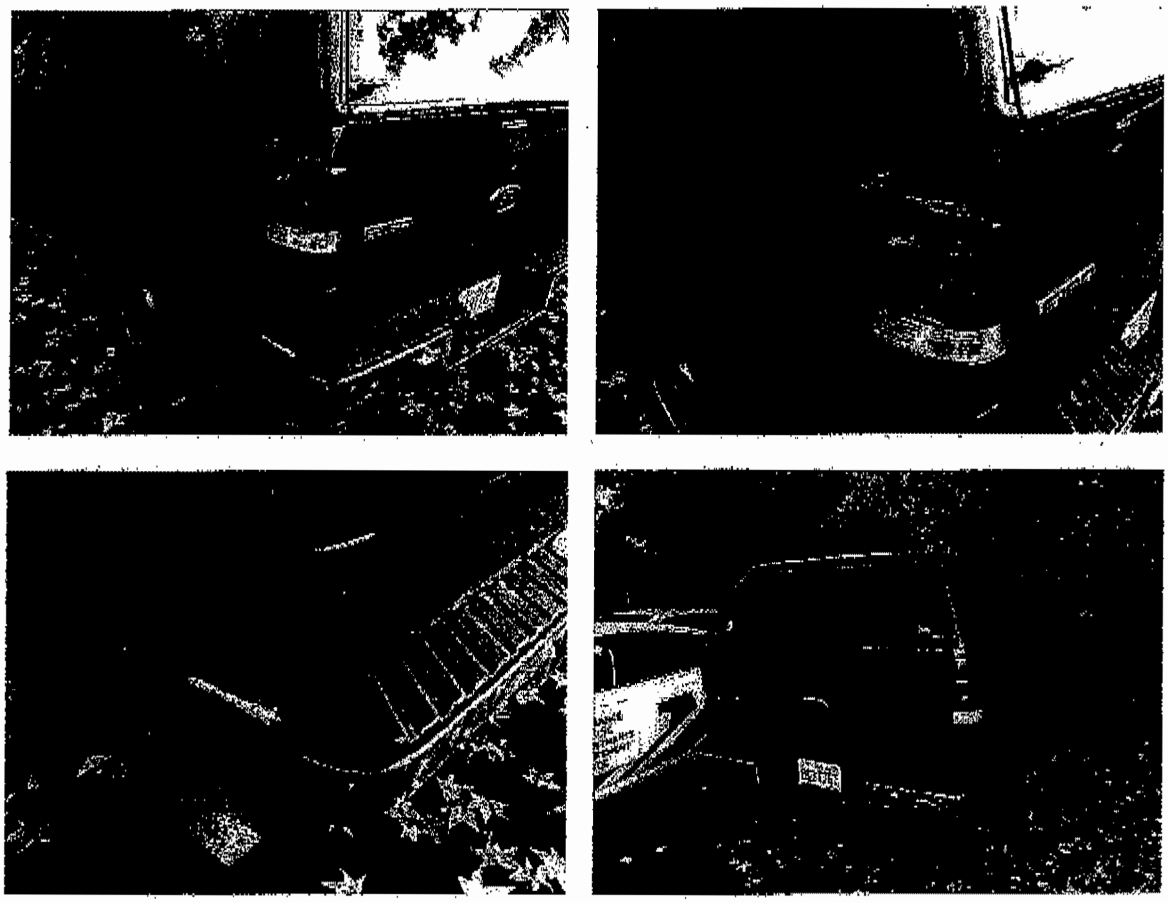

Figure 2: Reproductions of photographs of the subject 2008 Ford F150

The reviewed photographs of the incident UD2600 depicted a dent to the bottom edge of the right front corner of the box truck (Figure 3).

Figure 3: Reproduction of photograph of the incident 2004 UD2600 box truck

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Scientific analyses of the photographs and geometric measurements of the vehicles along with the available testimony, identified that the subject incident involved a shallow approach angle with vehicle interaction defined by sliding surfaces. As such, the subject incident was consistent with a sideswipe event.[8] The laws of physics dictate that the lateral force exerted to the rear left corner of the subject Ford F150 was a function of the friction generated between the interacting vehicle surfaces. Using a generally-accepted and peer-reviewed methodology, an exaggerated, worst case scenario peak acceleration to the incident as a result of the sideswipe event was less than 1.0g.[9] Using an acceleration pulse with the shape of a haversine and duration of 150 milliseconds,[10] the Delta-V associated with the subject incident is less than 1 mph. The lateral forces to the Ford F150 associated with the subject incident were calculated to be insignificant. Additionally, the above analysis is consistent with testing performed by the Insurance Institute for Highway Safety (IIHS) to assess the performance of an exemplar 2008 Ford F150.[11]

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that a person experiences 1g of loading while in a sedentary state. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[12] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

The laws of physics dictate that had there been enough energy transferred to initiate motion, the sideswipe event would have caused the subject Ford to accelerate longitudinally and slightly rightward. Scientific literature indicates that provided the low accelerations of the event, little occupant motion would have occurred.[13,14] ARCCA, Incorporated has conducted experiments that exposed motor vehicles to low severity contact events similar to the subject incident. These experiments included tracking the movement of human volunteers and anthropomorphic test devices (ATDs) during the testing. Results demonstrated that neither the human volunteers nor the ATDs experienced any significant motion relative to the vehicle's interior. If occupant motion were assumed to have occurred during the subject incident, the laws of physics and results from previous studies[15,16] dictate that an occupant would have tended to move rearward and slightly leftward relative to the vehicle's interior. This motion would have been controlled and supported

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8 Bailey, M.N., Wong, B.C., et al., (1995) Data and Methods for Estimating the Severity of Minor Impacts, (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

9 Toor, A., Roenitz, E., et al., (1999) Practical Analysis Technique for Quantifying Sideswipe Collisions, (SAE 1999-01-0094). Warrendale, PA, Society of Automotive Engineers.

10 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001) Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts. (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

11 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2004 Ford F-150, December 2003.

12 Mow, V.C. and W.C. Hayes, (1991) Basic Orthopaedic Biomechanics. New York, Raven Press.

13 Tanner, C.B., Wiechel, J.F., and Guenther, D.A., (2001). Vehicle and Occupant Response in Heavy Truck to Passenger Car Sideswipe Impacts (SAE 2001-01-0900). Warrendale, PA, Society of Automotive Engineers.

14 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

15 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

16 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

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by the friction generated at his seat bottom, the center console and the three point restraint. Specifically, the three-point restraint would have locked during the subject incident had the acceleration exceeded 0.7g and limited his forward body excursion.[17] Provided the low accelerations of the subject incident, and the supports described, an occupant would have been limited to well within normal physiological limits.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[18,19,20,21] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[22] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[23,24]

Studies by Rohlmann et al.[25,26,27] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[28] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[29]

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17 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

18 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

19 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

20 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

21 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

22 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

23 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

24 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

25 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics, 44*(8), 781-794.

26 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics, 27*(8), 754-758.

27 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics, 46*(3), 511-514.

28 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine, 29*(20), 2319-2329.

29 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

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It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On August 18, 2016, Mr. Dean Osborne was the seat belted driver of a 2008 Ford F150 that was contacted on the left rear corner by a 2004 UD2600 box truck resulting in a sideswipe collision.
2. The severity of the subject incident was consistent with a Delta-V less than 1.0 miles-per-hour with peak acceleration less than 1.0g.
3. Had the forces of the subject incident been sufficient to overcome the muscle reaction forces, the subject Ford would have been accelerated and pushed forward and slightly rightward, coupling an occupant's motion to the vehicle, and causing the body to load into the seat and seatback. All forces would have been within physiologic limits.
4. The acceleration experienced by Mr. Osborne was within the limits of human tolerance and comparable to that experienced during various daily activities.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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www.arcca.com

July 10, 2017

[redacted]

[redacted]

Dear [redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and biomechanical failures claimed by [redacted] in this incident. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

---

1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on January 10, 2014, [redacted] was the lap&shoulder belted driver of a 2007 Lexus IS 250 traveling southbound on Interstate 405. [redacted] was the driver of a 2010 Mazda Mazda3 traveling immediately behind the subject Lexus. As the Lexus was stopped for traffic, contact occurred between the rear of the subject Lexus and the front of the incident Mazda. No airbags were deployed and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. E300739*
- Fourteen (14) color photographic reproductions of the subject 2007 Lexus IS 250
- Twenty-four (24) color photographic reproductions of the incident 2010 Mazda Mazda3
- Supplement of Record 3 Summary for the subject 2007 Lexus IS 250 [May 24, 2014]
- Supplement of Record 1 with Summary for the incident 2010 Mazda Mazda3 [January 31, 2014]
- Deposition transcript of [redacted] [May 15, 2017]
- VinLink data sheet for the subject 2007 Lexus IS 250
- Expert AutoStats data sheets for a 2007 Lexus IS 250
- VinLink data sheet for the incident 2010 Mazda Mazda3
- Expert AutoStats data sheets for a 2010 Mazda Mazda3
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair documents for both the subject Lexus IS 250 and the incident Mazda Mazda3, in association with accepted scientific methodologies.[6,7]

The repair estimate for the subject Lexus reported damage to the rear bumper cover, left reflector, energy absorber, trunk emblem, rear bumper, rear body panel, trunk lid, and a frame pull was performed. The photographs depicted contact marks and scratches to the left side of the rear bumper cover, and a dent to the edge just below the left rear reflector (Figure 1).

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6 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

7 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Photographic reproductions of the subject 2007 Lexus IS 250

The repair estimate for the incident 2010 Mazda Mazda3 reported damage to the front bumper cover, license bracket, emblem, lower grille, absorber, absorber retainers, right lamp bezel, impact bar, center support, support plate, air deflector, radiator support, AC temp sensor, radiator, reservoir tank, headlamp assemblies, right rail extension, AC condenser assembly, hood/hinges, fenders, right apron assembly, and it was pulled for mash/sway. The photographs depicted the right side of the hood and front bumper cover displaced, and the front license plate was bent (Figure 2). The impact bar was crushed on the right side, and the radiator was displaced slightly rearward.

Figure 2: Photographic reproductions of the incident 2010 Mazda Mazda3

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred from the test. The damage to the Lexus IS 250, defined by the photographic reproductions and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[8] The IIHS tested a 2007 Lexus IS Series in a 6.2 mile-per-hour (mph) rear impact into a full-width barrier.[9] The tested Lexus sustained damage to the pull clamps, L/R rail, left quarter panel, rear body panel, rear bumper, rear bumper outer extensions, rear bumper cover, rear bumper reinforcements, rear bumper absorber, and required a frame measurement. The primary damage to the subject Lexus was to the rear bumper cover, left reflector, energy absorber, trunk emblem, rear bumper, rear body panel, trunk lid, and a frame pull was performed. Thus, because the Lexus IS Series in the IIHS rear impact test sustained similar damage to the subject Lexus, the severity and energy transfer of the IIHS impact is consistent with the severity of the subject incident. Therefore, when accounting for restitution, the subject Lexus IS 250 experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of approximately 8.0 mph.[10]

By the laws of physics, and using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with an 8.0 mph Delta-V impact is 2.4g.[11,12,13,14] Therefore, the average acceleration experienced by the subject Lexus IS 250 in which [redacted] was seated was 2.4g. This analysis is also consistent with an energy-based crush analysis to the front of a 2010 Mazda Mazda3.[15,16]

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8 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

9 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2007 Lexus IS, August 2007.

10 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

11 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

12 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

13 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

14 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

15 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

16 EDCRASH, Engineering Dynamics Corp.

Comparatively, hard braking generates average accelerations of approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that a person experiences 1g of loading while in a normal sedentary state. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[17] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Therefore, [redacted] experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

[redacted] testified, *"I recall my neck moved forward and back"*. This reported forward movement is contrary to the most basic laws of physics. The laws of physics dictate that when the subject Lexus IS 250 was contacted in the rear, it would have been pushed forward, causing [redacted] seat, which is attached to the vehicle, to also move forward relative to his body. This motion would result in [redacted] moving rearward relative to the interior of the subject vehicle and would cause him to load into the seatback structures. [redacted] torso and pelvis would settle back into the seatback and seat bottom cushions during this rearward motion. The available documents indicated [redacted] was wearing the available lap&shoulder belt restraint. Any rebound following the rear impact would have been within the range of protection afforded by the available lap&shoulder belt restraint system, and would have coupled [redacted] body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of [redacted] would have been limited to well within the range of normal physiological limits.

Research studies conducted using human volunteers have exposed subjects to rear-end impacts at comparable to and even greater severity than the subject incident.[18,19,20,21] This rear impact testing demonstrated that occupants moved rearward relative to the vehicle's interior until supported by the seat and seatback structures. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[22] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additional studies have been conducted using Anthropomorphic Test Devices (ATDs, or test

17 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

18 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

19 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

20 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

21 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

22 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

dummies), which measured spinal response to rear impact accelerations at severities greater than the subject incident.[23,24]

Studies by Rohlmann et al.[25,26,27] have shown that seemingly benign tasks, such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight, can generate loads that are comparable to or greater than those resulting from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[28] Additionally, Ng, et al,[29] studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident.

<u>Conclusions:</u>

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On January 10, 2014, [redacted] was the lap&shoulder belted driver of a 2007 Lexus IS 250 stopped on southbound Interstate 405, when contact occurred between the rear of his Lexus and the front of a 2010 Mazda Mazda3 at a low speed.

2. The severity of the subject incident was consistent with a rear impact of approximately 8.0 mph and an average acceleration of 2.4g.

3. Had there been enough energy transferred to cause any motion of the vehicle, the Lexus IS 250 would have been pushed and accelerated forward, coupling the occupant's motion to the vehicle, and causing the occupant's body to load into the seat and seatback structures.

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23 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

24 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

25 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

26 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

27 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

28 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

29 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

4. The acceleration experienced by [redacted] was within the limits of human tolerance and comparable to that experienced during various daily activities.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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September 5, 2017

[redacted]

[redacted]

[redacted]

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of [redacted]. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on August 3, 2012, [redacted] was laying cement in a driveway in the Manor Oaks development in Everett, Washington. [redacted] was the driver of a 1999 Mack RD6908 that was parked adjacent to the driveway and dispensing the cement out of a chute. [redacted] was troweling cement in the driveway. The Mack truck began rolling rearward and contact was made between the chute and [redacted]

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Five (5) black and white photographic reproductions of the subject 1999 Mack
- Eight (8) color photographic reproductions of the subject 1999 Mack
- Second Amended Complaint, [redacted] [June 16, 2017]
- Defendant's First Interrogatories and Responses, [redacted] [November 4, 2015]
- Plaintiff's Responses to Defendants First Interrogatories, [redacted] [March 8, 2016]
- Deposition transcript of [redacted] [February 14, 2017]
- Deposition transcript of [redacted] [April 13, 2017]
- Deposition transcript of [redacted] [May 25, 2017]
- Medical Records pertaining to [redacted]
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that [redacted] claims were caused by the subject incident on August 3, 2012;

6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity;
3. Determine [redacted] kinematic responses as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate [redacted] personal tolerances in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate [redacted] attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
  - Disc bulge at C5-C6
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
  - Disc bulge at L2-L3
- Right Shoulder
  - Sprain/strain
- Right hand
  - Sprain/strain
- Left Ankle
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the 1999 Mack RD6908 in association with accepted scientific methodologies. [11,12]

The photographs of the 1999 Mack RD6908 depicted no damage to the chute of the truck (Figure 1).

Figure 1: Reproductions of photographs of the subject 1999 Mack RD6908

According to [redacted] testimony, the truck driver, he exited the truck while it was in neutral due to a leg cramp. [redacted] testified that while he was outside of the Mack truck, it started rolling backwards. He testified that he "ran, caught up with it, set the brake" and the truck travelled approximately 6 feet during this time. [redacted] also states that the incident report only notes the truck tipping over a porta-john; he was not aware of the truck impacting a person. The sequence of events that [redacted] describes is that at least 6 seconds passed before he was able to stop the moving vehicle. Based on his testimony, the speed of the truck is estimated to be less than 1.0 mile-per-hour for this scenario.

According to [redacted] testimony, he was leveling with the raker and he felt a "blow on my back." He further testified that the contact of the truck "knocked me over to the left side". This reported leftward fall is contrary to the most basic laws of physics. Research has been performed on lateral destabilization of stepping responses and how postural stability is affected by contact from the

11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

side of the body. It was shown that accelerations of approximately 0.3g or below, applied in an oblique orientation, would produce postural instability.[13] Therefore, he did not experience excessive stretch, or movement, to his body. This indicates that a biomechanical failure mechanism based upon direct impact loading or inertial loading from a fall would not be present. The truck was travelling at a significantly low speed and [redacted] testified that he got up and was able to immediately rise and run, which is indicative of the impact being at a level of less than 0.3g.

The acceleration experienced due to gravity is 1g. This means that [redacted] experiences 1g of loading while in a sedentary state. Therefore, [redacted] experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces. [14] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

<u>Kinematic Analysis:</u>

[redacted] medical records indicated he was 66 inches in height, weighed approximately 200 lbs., and was 36 years old at the time of the subject incident. [redacted] testified that he was leveling the cement when he felt a "blow on my back." He also testified that the truck "knocked me over to the left side."

The laws of physics dictate that when the [redacted] was contacted in the back of the Mack truck, it would have pushed [redacted] and caused him to fall forward. This motion would result in [redacted] falling forward onto his hands and knees.

<u>Evaluation of Biomechanical Failure Mechanisms:</u>

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to [redacted] was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[15,16]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?

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13 B.E. Make, W.E. McIlroy, and S.D. Perry (1995). Influence of Lateral Destabilization on Compensatory Stepping Responses. *Journal of Biomechanics* **29(3)**: 343-353.
14 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.
15 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
16 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult; that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of protrusion, bulging, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc protrusion, bulging, and herniation involves a combination of hyperflexion or hyperextension, lateral bending, and compressive load.[17]

Cervical Spine

The available medical records indicated that a cervical spine MRI performed on September 11, 2012 showed a mild a circumferential disc bulge at C5-C6.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. During the subject incident, [redacted] body would have been pushed forward. The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[18,19,20,21] The available documents reported [redacted] was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[22]

17 White III, A.A. and M.M. Panjabi, (1990) Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

18 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

19 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

20 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

21 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

22 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of [redacted] cannot be made.

Thoracic and Lumbar Spine

The available medical records indicated that a lumbar spine MRI performed on October 5, 2012 indicated a moderate circumferential disc bulge L2-L3 and borderline congenital narrowing.

During an event such as the subject incident, the thoracic and lumbar spine of [redacted] is not compromised. Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident. [23,24,25,26] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[27,28] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[29] According to the available documents, [redacted] was capable of performing daily activities. A segmental analysis of [redacted] demonstrated that as he lifted objects during daily tasks, the forces applied to his lower spine would have been comparable to or greater than those during the subject incident.[30,31,32]

There would not be a compressive load applied to [redacted] thoracic or lumbar spine. Again, contact from the cement truck would tend to push [redacted] forward and not compress the thoracic or lumbar spine.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits

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23 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

24 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

25 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

26 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

27 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

28 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Thoracic and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

29 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

30 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

31 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

32 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

of [redacted] a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Right Shoulder and Hand

The available medical records indicated that a right shoulder MRI performed on June 19, 2013 showed mild rotator cuff tendinopathy, moderate biceps tendinopathy, and a questionable superior labral tear. Additionally, the records indicated an operation performed on November 27, 2013 and included right shoulder labral debridement, clavicle resection, and subacromial decompression.

During the subject incident, the [redacted] right shoulder and would not be directly loaded as he testified that he fell to the left. The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." Shoulder impingement syndrome, refers to inflammation of the rotator cuff tendons and the bursa (bursitis) that surrounds these tendons. Impingement syndrome is a result of the supraspinatus becoming entrapped between the anterior head of the humerus and acromion, coracoacromial ligament or the acromioclavicular joint.[33,34,35] A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[36] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[37]

Common activities would directly load [redacted] right shoulder multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[38,39,40,41] These data demonstrate that the shoulder forces and accelerations of the subject incident did not exceed [redacted] personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. Again, as

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33 Seeger, L.L., Gold, R.H., et al. (1988). "Shoulder Impingement Syndrome: MR Findings in 53 Shoulder." AJR, 150:343-347.

34 Murray, J-C. and Pelet, S. (2014). "Shoulder Impingement Syndrome Caused by a Voluminous Subdeltoid Lipoma." Case Reports In Orthopedics, Article ID 760219.3.

35 Escamilla, R.F., Hooks, T.R., Wilk, K.E. (2014). "Optimal management of shoulder impingement syndrome." Jounral of Sports Medicine, 2014:5 13-24.

36 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

37 Braun, S., Kokmeyer, D., and Millett, P.J., et al., (2009). *Shoulder Injuries in the Throwing Athlete*. Journal of Bone and Joint Surgery 91: 966-978.

38 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

39 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

40 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

41 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

noted above, if [redacted] fell to his left he would not expose his right shoulder or hand to direct contact forces. As this event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported right shoulder and right hand biomechanical failures of [redacted] cannot be made.

Left Ankle

The lateral ligament complex of the ankle is comprise of the anterior tibiofibular, calcaneofibular, and posterior talofibular ligaments.[42] Damage to these structures often occurs under plantar flexion (toe down) and inversion (base of foot towards the middle of the body) under a large load, such as in activities performed by athletes or military personal.[43] [redacted] testified that he felt a "blow on my back." This motion would have pushed his body forward, requiring him to step forward. However, [redacted] also testified that he was knocked over to the left. These actions could create the biomechanical failure mechanisms required for a left ankle biomechanical failure. However, the loading and kinematics of [redacted] ankle were well within the limits of human tolerance and physiological motion. Daily activities and occurrences such as walking, stumbling, single leg hopping, and jumping have been shown to have comparable and greater impact forces on the body.[44,45,46,47,48,49,50,51,52,53,54,55] These actions would apply direct and repetitive loads to [redacted] ankles of comparable or greater magnitude than he was exposed to during the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the left ankle. Finally, the forces created by the incident were well within the limits of human tolerance for the ankle, and were within the range typically seen in normal, daily activities. However, the event may have created the required biomechanical failure mechanism of [redacted] therefore a causal link between the subject incident and claimed ankle biomechanical failures cannot be ruled out.

---

42 Lynch, S.A. and Renström, Pr. A.F.H. (1999). Treatment of Acute Lateral Ankle Ligament Rupture in the Athlete. *Sports Medicine*, 27(1):61-71.

43 McCriskin, B.J. et al. (2015). Management and prevention of acute and chronic lateral ankle instability in athletic patient populations. *World Journal of Orthopedics*, 6(2): 161-171.

44 Keller, T.S., et al., (1996) "Relationship between vertical ground reaction force and speed during walking, slow jogging and running." *Clinical Biomechanics,* 11(5): 253-259.

45 Gottschall, J.S., Kram, R., (2005) "Ground reaction forces during downhill and uphill running." *Journal of Biomechanics,* 38: 445-452.

46 Bergmann, G., Graichen, F., Rohlmann, A., (2003) "Hip joint contact forces during stumbling." *Langenbecks Arch Surg,* 389:53-59.

47 Lindenberg, K.M., Garcia, C.R., (2013) "The influence of heel height on vertical ground reaction force during landing tasks in recreationally active and athletic collegiate females." *The International Journal of Sports Physical Therapy,* 8(1): 1-8.

48 Veilleux, L.N., Rauch, F., Lemay, M., Ballaz, L., (2012) "Agreement between vertical ground reaction force and ground reaction force vector in five common clinical tests." *J Musculoskeletal Neuronal Interact,* 12(4):219-223.

49 Kluitenberg, B., et al., (2012) "Comparison of vertical ground reaction forces during overground and treadmill running. A validation study." *BMC Musculoskeletal Disorders,* 1-8.

50 Schipplein, O.D, Andriacchi, T.P. (1991) "Interaction Between Active and Passive Knee Stabilizers During Level Walking." *Journal of Orthopaedic Research* 9: 113-119.

51 Nordin M. and Frankel V.H. (1989).Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

52 Taylor, W.R., Heller, M.O. et al. (2004). "Tibio-Femoral Loading During Human Gait and Stair Climbing." *Journal of Orthopaedic Research* 22: 625-632.

53 Devita, P. and Hortobagyi, T. (2003). "Obesity is Not Associated with Increased Knee Joint Torque and Power During Level Walking." *Journal of Biomechanics* 36: 1355-1362.

54 Gushue, D.L., Houck, J., Lerner, A.L. (2005). "Effects of Childhood Obesity on Three-Dimensional Knee Joint Biomechanics During Walking." *Journal of Pediatric Orthopedics* 25(6): 763-768.

55 Kaufman, K.R., Hughes, C., et al. (2001). "Gait Characteristics of Patients with Knee Osteoarthritis." *Journal of Biomechanics* 34: 907-915.

Personal Tolerance Values

According to the available documents, [redacted] worked as a concrete finisher and the duties included pouring and levelling cement. [redacted] also testified to playing volleyball and fishing as hobbies. These activities can produce greater movement, or stretch, to the soft tissues of [redacted] and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[56]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between [redacted] reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of [redacted] using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On August 3, 2012, [redacted] was laying cement in a driveway in Everett, Washington. [redacted] was troweling cement out of a chute of a 1999 Mack RD6908, when the truck began rolling backwards and reportedly contacted him at low speed. [redacted] testified that he subsequently fell to his left due to contact from the cement truck.
2. The severity of the subject incident was below 0.3g.
3. The acceleration experienced by [redacted] was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to [redacted] during the subject incident would tend to push [redacted] body forward.
5. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for [redacted] claimed shoulder and hand biomechanical failures. As such, a causal relationship between the subject incident and the shoulder and hand biomechanical failures cannot be made.

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56 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

8. A biomechanical failure mechanism cannot be ruled out in the subject incident to account for [redacted] claimed ankle biomechanical failures. As such, a causal relationship between the subject incident and the ankle biomechanical failures is possible.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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RECEIVED
SEP - 8 2017
LAW OFFICE OF
DAVID A. BUFALINI

September 7, 2017

Natalie Heineman, Esquire
Forsberg & Umlauf PS
901 Fifth Avenue
Suite 1400
Seattle, WA 98164

Re: *Grundl, Gregory and Tamieka v. Melinda Hendrick, DC, and Vision Quest Chiropractic and Massage d/b/a/ Life Force Chiropractic*
ARCCA Case No.: 3481-006

Dear Ms. Heineman:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and kinematics involved in the incident of Gregory Grundl. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the biomechanical community. [1,2,3,4] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

---

1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

3 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

4 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

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Incident Description:

According to the available documents, on May 21, 2015, Mr. Gregory Grundl was a patient of Melinda Hendrick, DC. On that date Ms. Hendrick performed a manual adjustment of Mr. Grundl's cervical spine. Mr. Grundl has claimed a C5-C6 and C6-C7 disc herniation as a result of the manual adjustment.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Complaint For Damages
- Medical records of Gregory Grundl
- Defendant Vision Quest Chiropractic And Massage's First Interrogatories And Requests For Production To Plaintiff Gregory Grundl
- Report of Leo Romero, May 20, 2016
- Report of Richard Wohns, September 1, 2016
- Deposition transcript of Melinda C. Hendrick, D.C., June 30, 2017
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Failure Summary:

The available documents indicate Mr. Grundl attributes the following biomechanical failures to the subject incident:

- Cervical Spine
  - C5-C6 disc herniation
  - C6-C7 disc herniation

Discussion:

At the time of the subject incident Mr. Grundl was lying on his back on a chiropractic treatment table. Melinda Hendrick was at the head of the table facing Mr. Grundl. She testified that she was low in a squat position with her arms at the same level as his head. Her hands were on the side of his neck with her finger on the lamina pedicle junction of the C2 vertebra. Mr. Grundl's head was laterally flexed to the right to the point of physiological resistance. The chart notes indicate Mr. Grundl's C2 was shifted right posteriorly.

Damage or biomechanical failure to intervertebral discs occurs when an environment creates both a mechanism for biomechanical failure and a force magnitude sufficient to exceed the strength capacity of the disc. Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[5]

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5 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

It has been noted that pre-existing degeneration can lower the mechanical strength and therefore the damage threshold of the cervical spine. In healthy subjects, a compressive force between 449 pounds and 703 pounds is a lower limit for cervical biomechanical failure such as bone fracture, annular ring tearing, or ligamentous tearing.[6] However, degenerative changes can decrease this limit to between 216 pounds and 268 pounds.[7],[8]

Hand grip strength is one of the common indices of human muscle strength. The strength capabilities of individual fingers has been studied. The type of movement performed by Melinda Hendrick can best be described as a 180 degree distal pad press. This is when the index finger is in line with the forearm and a force due to finger flexion is exerted at the pad of the finger. The mean strength a female is capable of for a finger press is approximately 35 Newtons.[9] This converts to a pound-force of 7.8. In addition, the manner in which the adjustment was performed would not generate any significant compression of the cervical spine. Finally, the area of adjustment, C2, is physically separated from C5-C6 and C6-C7 by other anatomic structures with energy absorbing capabilities.

Therefore, even in the presence of pre-existing degenerative changes the maximum force due to a finger press consistent with adjustment motion of Melinda Hendrick cannot exceed the limit for cervical biomechanical failure.

<u>Conclusions:</u>

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 21, 2015, Mr. Gregory Grundl received manual cervical adjustment of his cervical spine in the C2 region.
2. The maximum force due to the adjustment Melinda Hendrick testified to is insufficient to create a biomechanical failure mechanism for the claimed cervical biomechanical failures.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

---

6 Panjabi, M.M., Myers, B.S., Cervical Spine Protection Report, NOSAE, May 30, 1995

7 McElhaney, J. Doherty, B., Paver, J., Myers B., and Gray, L. Combined Bending and Axial Loading Responses of the Human Cervical Spine, SAE Preort No. 881709, 1988

8 Crowell, R.R., Shea, M., Edwards, W.T., Clothiaux, P.L., White, A.A. 3rd, Hayes, W.C., Cervical Injuries Under Flexion and Compression Loading. Journal of Spinal Disorders. 1993 Apr,6(2)

9 DiDomenica, A, Nussbaum, M., Measurement and prediction of single and multi-digit finger strength. Ergonomics, 2003, Vol. 46, No. 15, 1531-1548

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January 8, 2018

Ashraf Nomie, Esquire
Law Offices of Kathryn Reynolds Morton
650 NE Holladay Street
PO Box 4400
Portland, OR 97208-4400

Re: *Long, Elizabeth v. Tonya Latia Johnson*
Claim No.: 032520500
ARCCA Case No.: 2107-1461

Dear Mr. Nomie:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Elizabeth Long. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on August 20, 2015, Ms. Elizabeth Long was the seat-belted driver of a 2012 Honda Civic traveling on the southbound Interstate 5 off-ramp at Ehlen Road Northeast in Aurora, Oregon. A 2013 Subaru Impreza WRX was traveling immediately behind the subject Honda. While the Honda was stopped for traffic, contact was made between the rear of the subject Honda and the front of the incident Subaru. Both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Nineteen (19) color photographic reproductions of the subject 2012 Honda Civic
- Eleven (11) color photographic reproductions of the incident 2013 Subaru Impreza WRX
- Preliminary Estimate for repairs of the subject 2012 Honda Civic [September 9, 2015]
- Estimate for repairs of the subject 2012 Honda Civic [September 11, 2015]
- Estimate for repairs of the incident 2013 Subaru Impreza WRX [August 26, 2015]
- Plaintiff's demand letter [December 14, 2016]
- Deposition transcript of Elizabeth Long, *Elizabeth Long vs. Tonya Latia Johnson* [November 10, 2017]
- Medical Records pertaining to Elizabeth Long
- VinLink data sheet for the subject 2012 Honda Civic
- Expert AutoStats data sheets for a 2012 Honda Civic
- VinLink data sheet for the incident 2013 Subaru Impreza WRX
- Expert AutoStats data sheets for a 2013 Subaru Impreza WRX
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Long claims were caused by the subject incident on August 20, 2015;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

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2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2012 Honda Civic;
3. Determine Ms. Long's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Long's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Long attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair documents of the subject 2012 Honda Civic and incident 2013 Subaru Impreza WRX in association with accepted scientific methodologies.[11,12]

The repair documents for the subject 2012 Honda Civic reported damage to the rear bumper cover. The photographs depicted no significant crush to the rear bumper assembly, or displacement of the quarter panels, tail lamps, trunk lid, or floor pan (Figure 1). There were two bolt holes to the rear bumper cover, consistent with contact from a license plate bracket.

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

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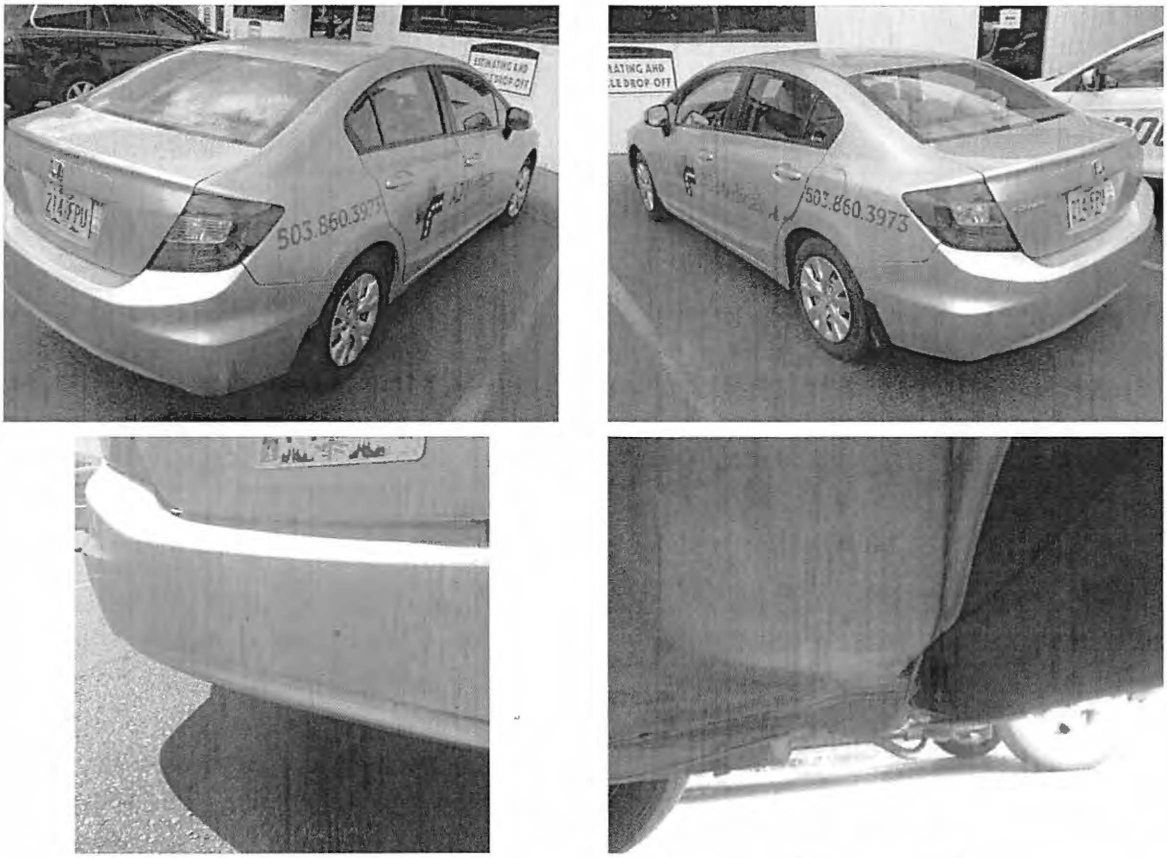

Figure 1: Reproductions of photographs of the subject 2012 Honda Civic

The repair documents for the incident 2013 Subaru Impreza WRX reported damage to the front bumper cover. The photographs depicted scrapes to the front bumper cover and the front license plate was bent (Figure 2). There was no significant crush to the front bumper cover, or displacement to the grille, bumper cover, headlamps, or hood.

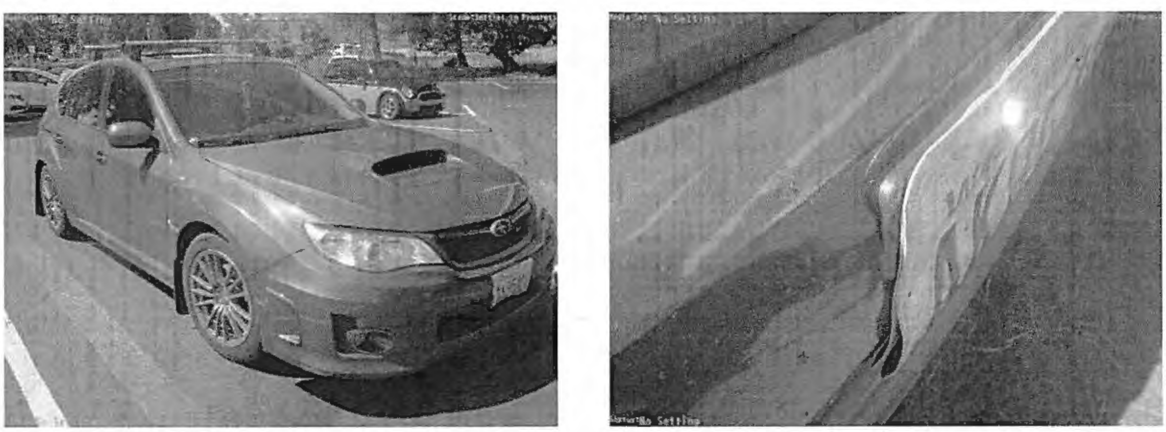

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Figure 2: Reproductions of photographs of the incident 2013 Subaru Impreza WRX

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Subaru Impreza, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested an exemplar 2013 Subaru Impreza in a 6.2 mile-per-hour frontal impact into a full-width barrier.[14] The test Subaru sustained damage to the front bumper and bumper cover, grille assembly, headlamps, radiator panel crossmember, and a realignment was performed. The primary damage to the incident Subaru Impreza was to the front bumper cover. Thus, because the test Subaru in the IIHS frontal impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident. Accounting for restitution and utilizing the Conservation of Momentum, the subject Honda Civic experienced a Delta-V of less than 9.8 miles-per-hour.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 9.8 mile-per-hour Delta-V is 3.0g.[15,16,17,18] By the laws of physics, the average acceleration experienced by the subject Honda Civic in which Ms. Long was seated was less than 3.0g. This analysis is consistent with an energy-based crush analysis to the front of a 2013 Subaru Impreza WRX. [19,20,21,22]

The acceleration experienced due to gravity is 1g. This means that Ms. Long experiences 1g of loading while in a sedentary state. Therefore, Ms. Long experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident.

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13 Siegmund, G.P., et al., (1996) Using *Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

14 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2008 Subaru Impreza, September 2008.

15 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

16 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

17 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

18 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

19 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

20 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

21 EDCRASH, Engineering Dynamics Corp.

22 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[23] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Long's medical records indicated she was 64 inches in height, weighed approximately 160 lbs., and was 53 years old at the time of the subject incident. Ms. Long indicated she was leaning forward and her head was turned to the right. She further stated that her hands were on the wheel, her foot was on the brake, and she made no contact with the interior of the subject Honda.

The laws of physics dictate that when the subject Honda Civic was contacted in the rear, it would have been pushed forward causing Ms. Long's seat to move forward relative to her body. This motion would result in Ms. Long moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Long's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Long was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Long's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Long would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Long was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure

23 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.
24 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
25 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

A cervical spine X-ray performed August 25, 2015 reported moderate loss of lordosis, minimal levo curvature, and minimal degenerative changes. There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

In a rear impact that produces motion of the subject vehicle, the Honda Civic would be pushed forward and Ms. Long would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar Honda Civic revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.75 inches in the full down position, and 34.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Long revealed she would have a normal seated height of 32.5 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Long's cervical spine would have undergone only a subtle degree of the characteristic response phases.[26] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[27] The cervical loads were within physiologic limits and Ms. Long would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[28,29,30]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[31,32,33,34,35] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several

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26 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

27 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

28 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

29 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

30 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

31 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

32 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

33 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

34 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

35 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[36] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g. [37,38,39,40] The available documents reported Ms. Long was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[41]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Long cannot be made. can't say medical

Thoracic and Lumbar Spine

A thoracic X-ray performed August 25, 2015 reported minimal degenerative changes and no recent fracture. A lumbosacral X-ray performed on August 25, 2015 reported mild degenerative changes at L4-S1, minimal levo curvature, and no significant variation of the femoral head, iliac crest, or sacral base height.

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Long is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Long's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

36 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

37 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

38 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

39 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

40 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

41 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[42,43,44,45] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[46] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[47,48] Ms. Long's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[49,50,51,52,53]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight along, with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[54,55,56,57] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or

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42 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

43 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

44 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

45 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

46 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

47 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

48 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

49 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

50 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

51 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, 7(3), 184-191.

52 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16(7), 549-559.

53 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

54 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, 44(8), 781-794.

55 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, 27(8), 754-758.

56 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, 46(3), 511-514.

57 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

greater than the subject incident.[58,59] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[60] According to the available documents, Ms. Long was capable of performing daily activities. A segmental analysis of Ms. Long demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[61,62,63]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Long, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made. cant say medical

Personal Tolerance Values

Ms. Long indicated that she was employed driving medical transportation for patients. She testified that she had 2 children, was capable of walking and driving, as well as cooking, cleaning, and doing laundry. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Long and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Long's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Long using peer-reviewed and generally-accepted methodologies.

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58 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

59 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

60 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

61 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

62 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

63 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

ARCCA INCORPORATED

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On August 20, 2015, Ms. Elizabeth Long was the seat-belted driver of a 2012 Honda Civic that was stopped on the southbound Interstate 5 off-ramp at Ehlen Road Northeast in Aurora, Oregon, when the subject Honda Civic was contacted in the rear at low speed by a 2013 Subaru Impreza WRX.
2. The severity of the subject incident was below 9.8 miles-per-hour with an average acceleration less than 3.0g.
3. The acceleration experienced by Ms. Long was within the limits of human tolerance and comparable to that experienced during various daily activities. OK
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Long's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Long's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made. Cant say medical
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Long's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made. can't say medical

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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January 12, 2018

Amy Freiman, Esquire
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N19 W24075 Riverwood Drive
Suite 333
Waukesha, WI 53188-1170

Re: *Turner, Debra v. FedEx Corp. v. Secura Supreme Ins. Co. and Rebecca Corrao*
File No.: 18.7498
ARCCA Case No.: 4961-004

Dear Ms. Freiman:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Debra Turner. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

Incident Description:

According to the available documents, on February 7, 2014, Ms. Debra Turner was the seat-belted driver of a 2007 Ford Econoline E250 traveling on Highway 32 near County Line Road in Racine County, Wisconsin. Ms. Rebecca Corrao was the driver of a 2003 Ford Escape traveling immediately behind the subject Ford E250. While the E250 was stopped at a traffic signal, contact was made between the rear of the subject Ford E250 and the front of the incident Ford Escape. Both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Wisconsin Motor Vehicle Accident Report, *Document Number MQ9S3SS*
- One (1) color photographic reproduction of the subject 2007 Ford Econoline E250
- One (1) color photographic reproduction of the incident 2003 Ford Escape
- Deposition transcript of Debra L. Turner, *Debra L. Turner et al vs. Secura Supreme Insurance Company et al* [November 8, 2017]
- Medical Records pertaining to Debra Turner
- VinLink data sheet for the subject 2007 Ford Econoline E250
- Expert AutoStats data sheets for a 2007 Ford Econoline E250
- Expert AutoStats data sheets for a 2003 Ford Escape
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Turner claims were caused by the subject incident on February 7, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2007 Ford Econoline E250;
3. Determine Ms. Turner's kinematic responses within the vehicle as a result of the subject incident;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Turner's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Turner attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracic Spine
    - Sprain/strain
- Lumbar Spine
    - Sprain/strain
    - L2-3 disc bulge and likely annular tear

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions of the subject 2007 Ford E250 and incident 2003 Ford Escape in association with accepted scientific methodologies.[11,12]

The photographic reproduction of the subject 2007 Ford E250 depicted rust and road wear to the rear bumper (Figure 1). There was extensive dirt and oxidization, though there was no significant crush to the rear of the vehicle. In her deposition, Ms. Turner testified that there was no damage to the subject vehicle.

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Photographic reproduction of the subject 2007 Ford Econoline E250

The photographic reproduction of the incident 2003 Ford Escape depicted damage to the front license plate (Figure 2). There was dirt and mud covering a majority of the front structures, though there was no significant crush to the front bumper cover. The bumper cover was out of alignment with the hood.

Figure 2: Photographic reproduction of the incident 2003 Ford Escape

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Ford Escape can be used to resolve the loads sustained by the subject Ford E250. That is, the loads sustained by the incident Escape are equal and opposite to those of the subject E250.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photographs and geometric measurements of the incident Ford Escape revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 mile per hour flat barrier impact to the front of an exemplar 2003 Ford Escape would result in significant and visibly noticeable crush across the

[13] Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

[14] Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

[15] Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

[16] Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

[17] Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

[18] EDCRASH, Engineering Dynamics Corp.

entirety of the subject Escape's front structure, with a residual crush of 2.75 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] Utilizing the Conservation of Momentum, the subject Ford E250 experienced a Delta-V of 6.3 miles-per-hour.

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Ford Escape, defined by the photographic reproductions was used to perform a damage threshold speed change analysis.[20] The IIHS tested an exemplar 2001 Ford Escape in a 5 mile-per-hour frontal impact into a full-width barrier.[21] The test Ford sustained damage to the front bumper reinforcement, bumper mounting plates, frame sidemembers, and hood. There is no significant damage to the incident Ford and no apparent hood damage. Thus, because the test Ford in the IIHS frontal impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident. Therefore, the subject E250 experienced a delta-V significantly below the above noted 6.3 miles-per-hour.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 6.3 mile-per-hour Delta-V is 1.9g.[22,23,24,25] By the laws of physics, the average acceleration experienced by the subject Ford E250 in which Ms. Turner was seated was less than 1.9g.

The acceleration experienced due to gravity is 1g. This means that Ms. Turner experiences 1g of loading while in a sedentary state. Therefore, Ms. Turner experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[26] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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[19] Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

[20] Siegmund, G.P., et al., (1996) *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

[21] Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2008 Subaru Impreza, September 2008.

[22] Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

[23] Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

[24] Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

[25] Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

[26] Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Kinematic Analysis:

Ms. Turner's medical records indicated she was 67 inches in height, weighed approximately 230 lbs., and was 51 years old at the time of the subject incident. Ms. Turner testified that her head contacted the head restraint, she was looking forward, and her hands were on the wheel. Her right foot was on the brake.

The laws of physics dictate that when the subject Ford E250 was contacted in the rear, it would have been pushed forward causing Ms. Turner's seat to move forward relative to her body. This motion would result in Ms. Turner moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Turner's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Turner was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Turner's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Turner would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Turner was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

A cervical X-ray performed February 10, 2014 reported no fracture or dislocation, and identified degenerative disc disease signs at C5-7 and C4-5. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of

27 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

28 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

In a rear impact that produces motion of the subject vehicle, the Ford E250 would be pushed forward and Ms. Turner would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 2007 Ford E250 revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is fixed at 33.25 inches. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Turner revealed she would have a normal seated height of 33.3 inches. Ms. Turner also testified that *"it was a higher seat"*, and recalled making contact with the head restraint. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Turner's cervical spine would have undergone only a subtle degree of the characteristic response phases.[29] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[30] The cervical loads were within physiologic limits and Ms. Turner would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[31,32,33]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[34,35,36,37,38] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[39] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

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29 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

30 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

31 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

32 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

33 Stemper, E.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

34 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

35 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal, 5*, 22-26.

36 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

37 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

39 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[40,41,42,43] The available documents reported Ms. Turner was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Turner cannot be made.

Thoracic and Lumbar Spine

A thoracic spine X-ray performed February 10, 2014 was reportedly negative. A lumbar X-ray performed the same day reported no fracture, possible facet degenerative changes at L4, and diminished disc height between the 4th lumbar vertebra and transitional vertebra. A lumbar MRI performed March 17, 2014 reported multilevel degenerative disc disease and facet arthropathy, as well as a disc bulge and possible annulus tear at L2-3. The records further indicate that a lumbar fusion was performed.

Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[45] In the absence of this acute biomechanical failure mechanism for disc failure, scientific investigations have shown that the above disc diagnoses can be the result of the normal aging process.[46,47]

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Turner is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Turner's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of

40 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

41 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

42 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

43 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

44 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

45 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

46 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

47 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[48,49,50,51] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[52] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[53,54] Ms. Turner's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[55,56,57,58,59]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[60,61,62,63] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or

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48 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

49 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

50 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

51 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

52 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

53 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

54 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

55 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

56 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

57 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, 7(3), 184-191.

58 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

59 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

60 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

61 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

62 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

63 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

greater than the subject incident.[64,65] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[66] According to the available documents, Ms. Turner was capable of performing daily activities. A segmental analysis of Ms. Turner demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[67,68,69]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Turner, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Personal Tolerance Values

Ms. Turner testified that she was employed as a service technician for FedEx drop boxes at the time of the subject incident. Her hobbies included bowling, roller skating, and throwing darts. She was capable of performing house chores, such as carrying laundry and carrying groceries. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Turner and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Turner's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Turner using peer-reviewed and generally-accepted methodologies.

64 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

65 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

66 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

67 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

68 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

69 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

ARCCA

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On February 7, 2014, Ms. Debra Turner was the seat-belted driver of a 2007 Ford Econoline E250 that was stopped on Highway 32 in Racine County, Wisconsin, when the subject E250 was contacted in the rear at low speed by a 2003 Ford Escape.
2. The severity of the subject incident was below 6.3 miles-per-hour with an average acceleration less than 1.9g.
3. The acceleration experienced by Ms. Turner was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Turner's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Turner's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Turner's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

ARCCA

BRADLEY W. PROBST, M.S.B.M.E.
PROFESSIONAL BIOGRAPHICAL OUTLINE

BACKGROUND

Mr. Probst earned a B.S. in Mechanical Engineering at University of Louisiana, Lafayette, Louisiana, and an M.S. in Biomedical Engineering at Tulane University, New Orleans, Louisiana. For his Ph.D. research at Tulane, Mr. Probst developed the most advanced kinematic model of the human cervical spine known to date. This unique model will be used to make technological advances to Naval pilot ejection and recovery systems. In addition, Mr. Probst has also done advanced course work in the fields of biomaterials, materials engineering, biosolid mechanics, mechanisms of bodily functions, and advanced finite element analysis. He has also lectured extensively and shared teaching responsibilities for courses in biomedical engineering and design and analysis at Tulane University.

As a biomedical consultant for a national accident investigation firm and while a student, Brad gained valuable experience in forensic analysis while working on a university project to research soft tissue injury caused by dynamic inertial loading.

While investigating and presenting work on bone morphology, his focus was the proper use of computation modeling as it related to bone material property identification. His significant contributions led to important developments in the field of bone mechanics and response of living bone to stress and disease.

SUMMARY OF EXPERIENCE

- Developed his skills in mechanical engineering while acting as project engineer at a petrochemical facility, where he was responsible for several multimillion-dollar expansion and renovation projects
- Pursued graduate research on a federally funded project to investigate spinal trauma and human head and neck tolerances to dynamic impact loadings
- Performed finite element analysis, computer modeling, material testing and data analysis
- Used advanced numerical methods for model validation
- Operated state-of-the-art high-speed computers to develop his calibrated model and to validate biofidelity
- Created an accurate biofidelic model of the kinematic response of the human head and neck during any general 3D acceleration through the development of a finite element model. The conclusions and results of this important project will be used to make technological advances toward improving the safety of pilots during ejection and major recovery system improvements
- Uses his biomedical and mechanical engineering skills to analyze the relationship of crash injuries to crash forces, occupant kinematics, and human tolerance
- Uses forensic investigation and accident reconstruction techniques to develop injury mitigation devices

AREAS OF SPECIALTY

- Biomechanical Consulting
- Human Injury Tolerance
- Vehicular Accident Reconstruction
- Impact and Inertial Trauma Analysis
- Injury Mechanism and Mitigation Analysis
- Slip and Fall Analysis

ACADEMIC BACKGROUND

- Tulane University, New Orleans, LA, Ph.D. Candidate, Biomedical Engineering
- Tulane University, New Orleans, LA, M.S., Biomedical Engineering, 1996
- University of Louisiana, Lafayette, LA, B.S., Mechanical Engineering, 1988

PROFESSIONAL EXPERIENCE

January 2000 – Present | ARCCA, Incorporated | Senior Biomechanist

- Specializes in injury analysis, injury mechanism determination and crash kinematics
- Practices biomechanics to explore the cause, nature and severity of injuries
- Utilizes medical records, testing, computer modeling and his extensive knowledge of human injury tolerance to determine whether a claimed injury is consistent with a specific set of actions or exposure to a specific accident environment

1995 – 2000 | Tulane University | Research Assistant

- Pursued graduate research on a spinal trauma investigation and analysis project funded by the Office of Naval Research. His position was secured, fully funded and compensated through competitive selection
- Performed finite element analysis, computer modeling, material testing, and data analysis to develop biofidelic human cervical spine analog
- Utilized advanced numerical methods for model validation
- Proposed conclusions and research results that will be used to implement technological advancements in naval pilot ejection and recovery systems

1997 – 1999 | Unified Investigations & Sciences, Inc. | Biomechanical Consultant

- Performed forensic analysis of soft tissue injury from mild impact in automotive accidents
- Determined impact levels through vehicular accident reconstruction, and compared findings to determine injury causation and severity
- Presented written conclusions to clients and provided expert testimony relative to his findings

May 1995 – 1999 | Tulane University | Teaching Assistant

- Selected by faculty mentor to assist with and share teaching responsibilities for courses such as Statics, Introduction to Biomedical Engineering and Design and Analysis
- Collaborated with mentor to plan lectures
- Prepared of course material
- Presented lectures

1988 – 1995 | Wink Engineering | Mechanical/Project Engineer

- Managed and was responsible for several multimillion-dollar expansion and renovation projects at a petrochemical facility
- Directed and performed environmental remediation (air and water)
- Recommended and implemented improvements to waste water treatment systems

PROFESSIONAL AFFILIATIONS

- Association for the Advancement of Automotive Medicine
- Society of Automotive Engineers (SAE)
- American Society of Safety Engineers (ASSE)
- American Society of Mechanical Engineers (ASME)

PUBLICATIONS

Probst, B, R. Anderson, G. Harris, R. Hart. (2007). *A Three-Dimensional Nonlinear Kinematic Finite Element Model of the Human Cervical Spine Under Dynamic Inertial Loading.* American Society of Biomechanics Biomechanics Symposium 2007, Stanford University: ASB.

Cantor, A., M. Markushewski, L. D'Aulerio, B. Benda, D. Eisentraut, **B. Probst**, L. Sicher. (2007). *Seat Design: A Risk Benefit Approach.* ASSE.

Probst, B. (Presenter). (2007). *Industrial vs. Academic Perspectives on Bioengineering Education.* ASME Summer Bioengineering Conference. Keystone, CO: ASME.

Probst, B., R. Anderson, T. Hart, G. Harris, S. Guccione. (2007). *A Three-Dimensional Nonlinear Kinematic Finite Element Model of the Human Cervical Spine Under Dynamic Inertial Loading.* American Society of Biomechanics Northwest Biomechanics Symposium 2007, Eugene, Oregon: ASB.

Markushewski, M., Gushue, D., **Probst, B.**, Coward, C., (2007). *When Driver Safety Fails—Then What? Vehicular Accident Analysis: The Big Picture.* ASSE.

Gushue, D.L., Joganich, T., **Probst. B. W.**, Markushewski, M. (2007). *Biomechanics for Risk Managers—Analysis of Slip, Trip & Fall Injuries.* ASSE.

Gushue, D., **B. Probst**, et al. (2006). *Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts.* Safety 2006, Seattle, WA, ASSE.

Benda, B. J., L. D'Aulerio, A. Cantor, M. L. Markushewski, **B. Probst**, et al. (2006). *Performance of Automotive Seat Belts During Inverted (-Gz) Rollover Drop Tests.* Icrash 2006—International Crashworthiness Conference, Athens, Greece, University of Bolton.

Coleman, J.C., **Probst, B.W.**, Roberts, M.D., and Hart, R.T. (1999). *Meshes Based On Cube-Shaped Finite Elements Do Not Converge: Quadratic Tetrahedral Elements Are An Alternative. Proceedings of the 1999 Summer Bioengineering Conference (ASME)* Big Sky, MT, June 1999. (pp. 329-230) New York: ASME.

Coleman, J.C., **Probst, B.W.**, Roberts, M.D., and Hart, R.T. (1998). *Investigating the Convergence Behavior of Voxel-Based Finite Element Meshes. Proceedings of the 7th Annual Symposium on Computational Methods in Orthopaedic Biomechanics*, Anaheim, CA, February 1998. Chicago: Orthopaedic Research Society (ORS).

COURSE INSTRUCTION

- *Slip/Trip/Falls*, Rocky Mountain IASIU Chapter, Denver, CO. May 7, 2009
- *Biomechanics*, Puget Sound Special Investigators, Seattle, WA. July 30, 2009
- *Slip/Trip/Falls*, Las Vegas IASIU Chapter, Las Vegas, NV. December 7, 2009
- *Low Speed Impacts*, Oregon IASIU Chapter, Portland, OR. May 4, 2010
- *Slip/Trip/Falls*, Oregon IASIU Chapter, Portland, OR. Oct 7, 2011
- *Biomechanics*, Hawaii RIMS Chapter, Honolulu, HI. September 15, 2011
- *Determining Injury Causation*, Alaska RIMS Chapter, Anchorage, AK. October 19, 2011
- *Biomechanics*, OR RIMS Chapter, Portland, OR. June 20, 2013
- *Determining Injury Causation*, Los Angeles RIMS Chapter, September 17, 2014

OTHER PROFESSIONAL ACTIVITIES

Judge at the Edmonds Annual Hot Autumn Nites Car Show, Edmonds, WA, September 6, 2008 sponsored by the Greater Edmonds Chamber of Commerce

FILED
02-21-2018
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DANE COUNTY, WI
2017CV000343

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February 13, 2018

Daniel J. O'Brien, Esquire
Halling & Cayo, SC
320 East Buffalo Street
Suite 700
Milwaukee, WI 53202

Re: *Kamholz, Larry and All Savers Ins. Co. v. State Farm and Christopher Peck*
ARCCA Case No.: 3683-014

Dear Mr. O'Brien:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Larry Kamholz. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

EXHIBIT
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3

Incident Description:

According to the available documents, on May 19, 2015, Mr. Larry Kamholz was the seat-belted driver of a 2011 Lincoln MKS traveling on Verona Road in Madison, Wisconsin. Mr. Christopher Peck was the driver of a 2009 Toyota Prius traveling immediately behind the subject Lincoln MKS. While stopped in traffic, contact was made between the rear of the subject Lincoln MKS and the front of the incident Toyota Prius.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Wisconsin Motor Vehicle Accident Report [May 19, 2015]
- Answers to Interrogatories, *Larry Kamholz v. Christopher Peck*
- Eleven (11) photographic reproductions of the subject 2011 Lincoln MKS
- Seventeen (17) color photographic reproductions of the incident 2009 Toyota Prius
- Estimate for the subject 2011 Lincoln MKS [June 12, 2015]
- Estimate for the incident 2009 Toyota Prius [May 20, 2015]
- Supplement 1 for the incident 2009 Toyota Prius [May 28, 2015]
- Supplement 2 for the incident 2009 Toyota Prius [June 2, 2015]
- Deposition transcript from Larry Kamholz [January 4, 2018]
- Medical Records pertaining to Larry Kamholz
- VinLink data sheet for the subject 2011 Lincoln MKS
- Expert AutoStats data sheets for a 2011 Lincoln MKS
- VinLink data sheet for the incident 2009 Toyota Prius
- Expert AutoStats data sheets for a 2009 Toyota Prius
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

1. Identify the biomechanical failures that Mr. Kamholz claims were caused by the subject incident on May 19, 2015;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2011 Lincoln MKS;
3. Determine Mr. Kamholz's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. Kamholz's personal tolerances in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Mr. Kamholz attributes the following biomechanical failures as a result of the subject incident:

- Lumbar Spine
    - Sprain/strain
    - L5-S1 disc protrusion

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2011 Lincoln MKS and the incident 2009 Toyota Prius in association with accepted scientific methodologies. [11,12]

The repair estimate for the subject 2011 Lincoln MKS reported damage to the rear bumper upper cover, rear bumper lower cover, rear bumper absorber, and rear bumper mounting right bracket. The available photographs depicted small indents to the rear bumper cover (Figure 1).

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

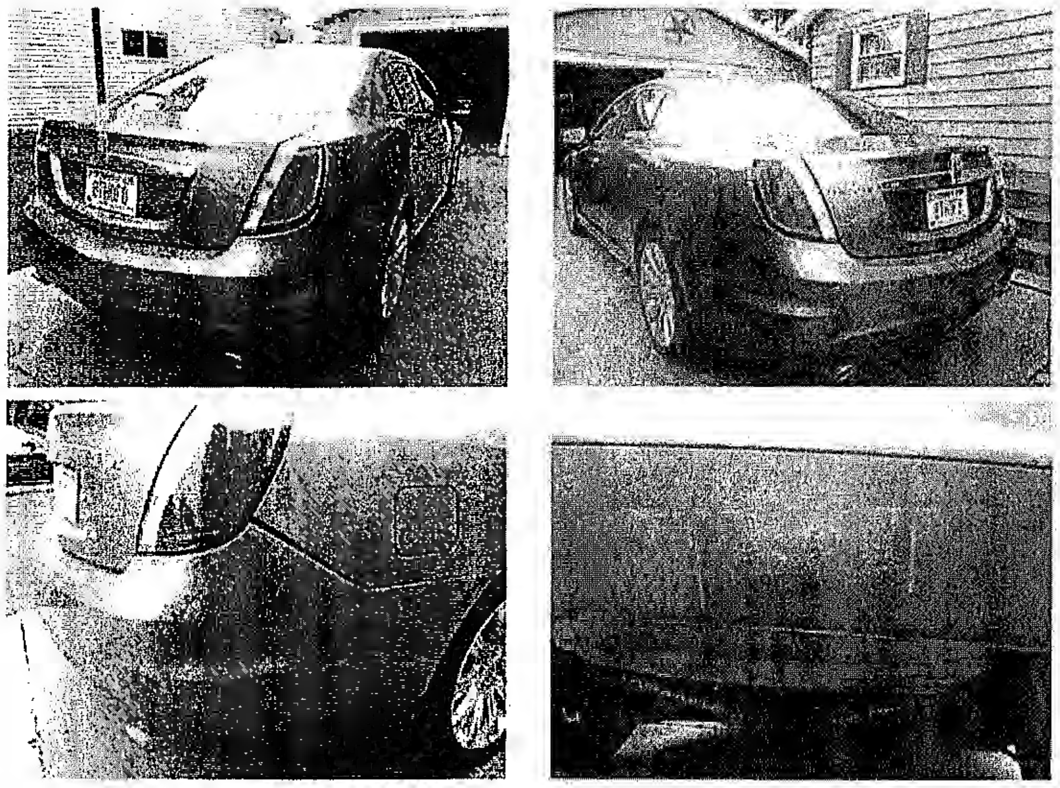
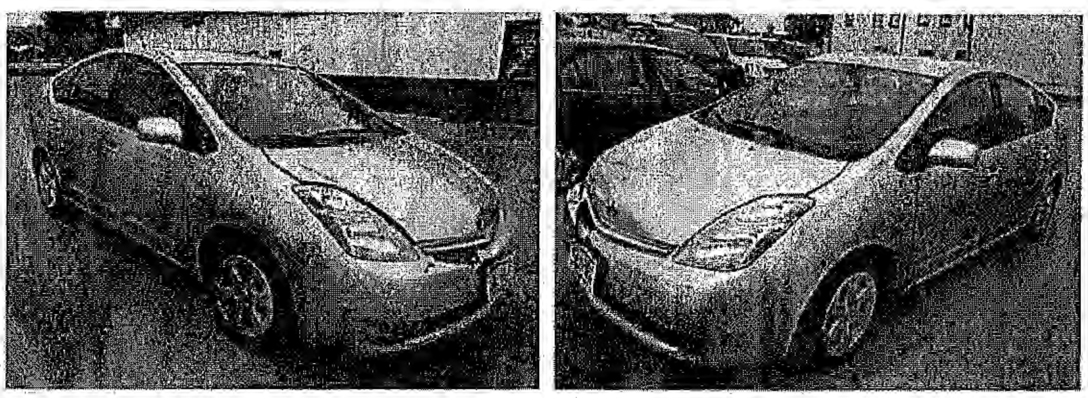


Figure 1: Reproductions of photographs of the subject 2011 Lincoln MKS

The repair documents for the incident 2009 Toyota Prius indicated there was damage to the front bumper cover, front bumper reinforcement, left/right lower front bumper grille, lower front bumper grille, front bumper cover lower molding, front license plate bracket, left halogen headlamp assembly, left radiator side panel, hood panel, hood panel emblem, left/right hood panel hinge, and left/right fender nameplate. The photographs depicted residual crush to the front of the hood and cracks to the front bumper cover (Figure 2).



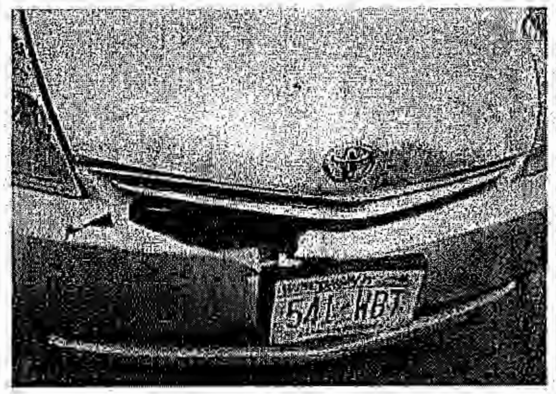


Figure 2: Reproductions of photographs of the incident 2009 Toyota Prius

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the incident Toyota Prius, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested an exemplar Toyota Prius in a 6.2 mile-per-hour rear impact into a flat barrier.[14] The test Toyota Prius sustained damage to the front bumper cover, front bumper reinforcement, front bumper absorber, left/right headlamp mounting bracket, hood panel, hood panel emblem, hood panel latch, and hood lock vertical support. The damage is shown in Figure 3. The primary damage to the subject incident Toyota Prius was to the front bumper cover, front bumper reinforcement, left/right lower front bumper grille, lower front bumper grille, front bumper cover lower molding, front license plate bracket, left halogen headlamp assembly, left radiator side panel, hood panel, hood panel emblem, light/right hood panel hinge, and left/right fender nameplate. Thus, because the test Toyota Prius in the IIHS frontal impact test sustained similar damage, the severity and energy transfer of the IIHS impact is similar compared to the severity of the subject incident and places the Toyota Prius speed at the test speed of 5 miles-per-hour. Using conservation of momentum with a coefficient of restitution of 0.3, the subject Lincoln MKS experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of 8.6 miles-per-hour or less.[15,16]

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13 Siegmund, G.P., et al., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA. Society of Automotive Engineers.

14 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2008 Toyota Prius, September 2008.

15 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

16 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

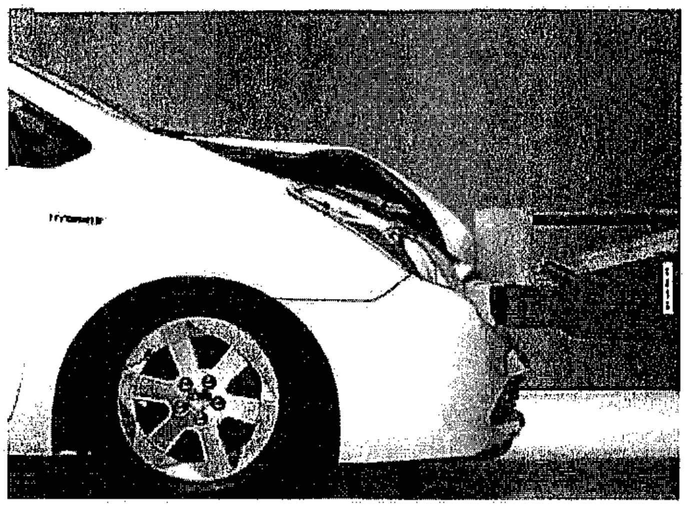

Figure 3: Reproduction of photograph of test Toyota Prius

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with an 8.6 mile-per-hour Delta-V is 2.6g.[17,18,19,20] By the laws of physics, the average acceleration experienced by the subject Lincoln MKS in which Mr. Kamholz was seated was significantly less than 2.6g.

The acceleration experienced due to gravity is 1g. This means that Mr. Kamholz experiences 1g of loading while in a sedentary state. Therefore, Mr. Kamholz experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[21] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Mr. Kamholz's medical records indicated he was 73 inches in height, weighed approximately 212 lbs., and was 42 years old at the time of the subject incident. Mr. Kamholz testified that he was "getting jolted forward" and then, "after the initial force forward, it jolted back." He also doesn't recall hitting anything on the interior.

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17 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration.* (No. 2000-01-0880). SAE Technical Paper.

18 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

19 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts.* (No. 970120). SAE Technical Paper.

20 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

21 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

The laws of physics dictate that when the subject Lincoln MKS was contacted in the rear, it would have been pushed forward causing Mr. Kamholz's seat to move forward relative to his body. This motion would result in Mr. Kamholz moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Mr. Kamholz's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Mr. Kamholz was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Mr. Kamholz's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Kamholz would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Kamholz was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[22,23]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Lumbar Spine

The available medical records indicated a lumbar spine X-ray performed on May 19, 2015 and the results showed disc space narrowing and progressive degenerative change at L3-L4. Additionally, a lumbar spine X-ray was performed on June 12, 2015 and the results showed no evidence of fracture or static subluxation, mild levoscoliosis and degenerative disc disease. Further, a lumbar spine MRI was performed on June 23, 2015 and the results showed multilevel lumbar spine degenerative changes

22 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.
23 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck.* (No. 710855). SAE Technical Paper.

greatest at L5-S1, possible mild compression of the exiting left L5 nerve root and posterior deflection of the transversing left S1 nerve root.

During an event such as the subject incident, the lumbar spine of Mr. Kamholz is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Mr. Kamholz's lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[24,25,26,27] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[28] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[29,30] Mr. Kamholz's lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[31,32,33,34,35]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the

24 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

25 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

26 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

27 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

28 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

29 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

30 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

31 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

32 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

33 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

34 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

35 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

subject incident.[36,37,38,39] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[40,41] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[42] According to the available documents, Mr. Kamholz was capable of performing daily activities. A segmental analysis of Mr. Kamholz demonstrated that as he lifted objects during daily tasks, the forces applied to his lower spine would have been comparable to or greater than those during the subject incident.[43,44,45]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Kamholz, a causal link between the subject incident and claimed lumbar biomechanical failures cannot be made.

Personal Tolerance Values

According to the available documents, Mr. Kamholz worked as a model and also owned a crisis consulting management firm. He also testified to going to the gym five times per week. These activities can produce greater movement, or stretch, to the soft tissues of Mr. Kamholz and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[46]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the

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[36] Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

[37] Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

[38] Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

[39] Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

[40] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

[41] Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Thoracic and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

[42] Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

[43] Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA. Lippincott Williams & Wilkins.

[44] Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

[45] Chaffin, DB, Andersson, GBJ, Moring, BJ, (1999) Occupational Biomechanics, Third Edition. Wiley-Interscience

[46] Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Kamholz's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Kamholz using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 19, 2015, Mr. Larry Kamholz was the seat-belted driver of a 2011 Lincoln MKS that was stopped on Verona Road in Madison, Wisconsin, when the subject Lincoln MKS was contacted in the rear at low speed by a 2009 Toyota Prius.
2. The severity of the subject incident was below 8.6 miles-per-hour with an average acceleration less than 2.6g.
3. The acceleration experienced by Mr. Kamholz was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Kamholz's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Kamholz's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Kamholz's claimed lumbar biomechanical failures. As such, a causal relationship between the subject incident and the lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

ARCCA
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March 1, 2018

Joel Petersen, Esquire
Allstate Staff Counsel
1000 SW Broadway, Suite 1080
Portland, OR 97205

Re: *Chicas, Estella v. Makenna Cunningham*
ARCCA Case No.: 1017-245

Dear Mr. Petersen:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Estella Chicas. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

ARCCA INCORPORATED

Incident Description:

According to the available documents, on May 23, 2015, Ms. Estella Chicas was the seat-belted driver of a 2005 Scion xA traveling on South Meyers Road in Oregon City, Oregon. Ms. Makenna Cunningham was the driver of a 2001 Saturn L200 travelling immediately behind the subject Scion. While the Scion was stopped in traffic, contact was made between the rear of the subject Scion xA and the front of the incident Saturn L200. Both vehicles were towed from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Oregon Police Traffic Crash Report, *Case No. 15-1698*
- Thirty-six (36) color photographic reproductions of the subject 2005 Scion xA
- Four (4) color photographic reproductions of the incident 2001 Saturn L200
- Estimate of Record of repairs for the subject 2005 Scion xA [May 29, 2015]
- Complaint, *Estella Chicas v. Makenna Cunningham* [May 4th, 2017]
- Deposition transcript of Makenna Cunningham, *Estella Chicas vs. Makenna Cunningham* [October 23, 2017]
- Deposition transcript of Estella Chicas, *Estella Chicas vs. Makenna Cunningham* [November 29, 2017]
- Medical Records pertaining to Estella Chicas Which ones?
- VinLink data sheet for the subject 2005 Scion xA
- Expert AutoStats data sheets for a 2005 Scion xA
- VinLink data sheet for the incident 2001 Saturn L200
- Expert AutoStats data sheets for a 2001 Saturn L200
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Chicas claims were caused by the subject incident on May 23, 2015;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2005 Scion xA;
3. Determine Ms. Chicas's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Chicas's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Chicas attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
  - L3-4 disc protrusion and annular tear
  - L4-5 disc bulge
- Bilateral Sacroiliac Joint
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair estimates of the subject 2005 Scion xA, and photographic reproductions of the incident 2001 Saturn L200, in association with accepted scientific methodologies.[11,12]

The repair documents to the subject Scion reported damaged to the muffler and pipe, sill panel retainer, left rear lamp lens and housing, mud guards, right side seal, rear bumper cover, bumper mounting brackets, left side seal, rear body and floor, right rear side seal, lift gate, and muffler absorber mount. The photographs depicted scrapes and gouges to the rear bumper cover, which was

Frame ??

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

displaced relative to the left quarter panel (Figure 1). The floor pan and reinforcement bar were also damaged.

Fignre 1: Reproductions of photographs of the subject 2005 Scion xA

The photographs of the incident Saturn L200 depicted scrapes to the top of the front bumper cover, and crush to the grille (Figure 2). The headlamps were displaced, and the hood was crushed rearward. Given the amount of crush above the front bumper cover, compared with the low crush to the front bumper cover, the subject incident is consistent with an underride/override event. This means that the front bumper of the incident Saturn did not directly engage the rear bumper of the subject Scion. Rather, the Saturn's front bumper was below the Scion's rear bumper, which causes substantially more residual crush to the front components of the Saturn due to air space and non-structural components, compared to direct bumper contact at a similar speed. Peer-reviewed and generally-accepted methodologies for conducting residual crush measurements involve averaging the resulting deformation and revising the stiffness coefficients to determine the critical residual crush when an underride/override condition is present.[13,14]

13 Tumbas, N.S., and Smith, R.A., (1988). Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

14 Tavakoli, M.S., et al (2007). Estimation of Frontal Crush Stiffness Coefficients for Car-to-Heavy Truck Underride Collisions (SAE 2007-01-0731). Warrendale, PA, Society of Automotive Engineers.

Figure 2: Reproductions of photographs of the 2001 Saturn L200

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Saturn L200 can be used to resolve the loads sustained by the subject Scion xA. That is, the loads sustained by the incident Saturn are equal and opposite to those of the subject Scion.

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[15,16,17,18,19] Analyses of the photographs and geometric measurements of the incident Saturn L200 revealed the damage due to the subject incident. Accounting for underride, an energy crush analysis indicates that a single 10 mile per hour flat barrier impact to the front of an exemplar Saturn L200 would result in significant and visibly noticeable crush across the entirety of the subject Saturn's front structure, with a residual crush of 7.0 inches.[20] Therefore, the energy crush analysis shows greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[21] Utilizing the Conservation of

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15 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

16 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

18 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

19 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

20 EDCRASH, Engineering Dynamics Corp.

21 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

Momentum and accounting for the difference in mass of the involved vehicles, the subject Scion experienced a Delta-V of 12.4 miles-per-hour.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 12.4 mile-per-hour Delta-V is 3.8g.[22,23,24,25] By the laws of physics, the average acceleration experienced by the subject Scion in which Ms. Chicas was seated was less than 3.8g.

The acceleration experienced due to gravity is 1g. This means that Ms. Chicas experiences 1g of loading while in a sedentary state. Therefore, Ms. Chicas experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[26] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Chicas's medical records indicated she was 64 inches in height, weighed approximately 185 lbs., and was 46 years old at the time of the subject incident. She testified that she was stopped with her hands on the wheel, and that she was sitting upright. She did not make contact with the interior of the vehicle. She testified that her body *"felt like going forward and back"*.

The laws of physics dictate that when the subject Scion xA was contacted in the rear, it would have been pushed forward causing Ms. Chicas's seat to move forward relative to her body. This motion would result in Ms. Chicas moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Chicas's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Chicas was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Chicas's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Chicas would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Chicas was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there

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22 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration.* (No. 2000-01-0880). SAE Technical Paper.

23 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

24 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts.* (No. 970120). SAE Technical Paper.

25 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

26 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

A cervical spine X-ray performed May 23, 2015 reported no evidence of fracture. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

In a rear impact that produces motion of the subject vehicle, the Scion xA would be pushed forward and Ms. Chicas would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar Scion xA revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.25 inches in the full down position, and 33.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Chicas revealed she would have a normal seated height of 32.7 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Chicas's cervical spine would have undergone only a subtle degree of the characteristic response phases.[29] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant

209,297
miles

[27] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[28] Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

[29] Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

cervical loads.[30] The cervical loads were within physiologic limits and Ms. Chicas would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[31,32,33]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[34,35,36,37,38] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[39] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[40,41,42,43] The available documents reported Ms. Chicas was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[44]

30 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

31 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

32 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Hnman Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Antomotive Engineers.

33 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

34 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

35 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Hnman Subjects. *Accident Reconstruction Journal, 5*, 22-26.

36 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 6*(6), 366-375.

37 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

38 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

39 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold dnring simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

40 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410.

41 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30.

42 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

43 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

44 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living.* (No. 2006-01-0247). SAE Technical Paper.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Chicas cannot be made.

Thoracic, Lumbar Spine and Sacroiliac Joint

A lumbar MRI performed September 12, 2016 reported mild multilevel degenerative changes, a small circumferential disc bulge at L3-4, and a small focal disc protrusion and midline annular fissure at L4-5. A later lumbar MRI performed September 18, 2015 reported a small central disc protrusion and mild broad-based disc bulging with an anterior annular tear or fissure at L3-4, broad based disc bulging at L4-5, facet joint effusion at L3-4 and L4-5, and discogenic changes at L3-4. A lumbosacral X-ray performed September 17, 2015 reported no acute fracture. Ms. Chicas underwent a right sacroiliac joint fusion on June 20, 2016.

Disc biomechanical failure can result from chronic degeneration of the disc itself or from acute insult, that is, a single event wherein forces are applied to the disc at magnitudes beyond its capacity or strength. Damage (biomechanical failure) to the disc in the form of a bulge, protrusion, or herniation can result. Based upon previous research, the accepted mechanism for acute intervertebral disc bulge, protrusion, or herniation involves a combination of hyperflexion or hyperextension and lateral bending with an application of a sudden compressive load.[45] In the absence of this acute biomechanical failure mechanism for disc failure, scientific investigations have shown that the above disc diagnoses can be the result of the normal aging process.[46,47]

During an event such as the subject incident, the thoracolumbar spine and sacroiliac joints of Ms. Chicas are well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Chicas's thoracolumbar spine and sacroiliac joints. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracolumbar spine and sacroiliac joints. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracolumbar spine and sacroiliac joints; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[48,49,50,51] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and

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45 White III, A. A. and M. M. Panjabi (1990). Clinical Biomechanics of the Spine. Philadelphia, J.B. Lippincott Company.

46 Kambin, P., Nixon, J.E., Chait, A., et al. (1988). "Annular Protrusion: Pathophysiology and Roentgenographic Appearance." Spine 13(6): 671-675.

47 Roh, J.S., Teng, A.L., Yoo, J.U., et al., (2005). "Degenerative Disorders of the Lumbar and Cervical Spine." Orthopedic Clinics of North America 36: 255-262.

48 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

49 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

50 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

51 Weiss M.S., Lustick L.S., Guidelines for Safe Hnman Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

What speed are these done?

lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[52] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[53,54] Ms. Chicas's thoracolumbar spine and sacroiliac joints would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[55,56,57,58,59]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[60,61,62,63] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[64,65] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[66] According to the available documents, Ms. Chicas was capable of performing daily activities. A segmental analysis of Ms. Chicas demonstrated

52 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

53 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position ou the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

54 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

55 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

56 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

57 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, 7(3), 184-191.

58 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

59 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

60 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

61 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

62 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

63 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

64 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

65 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

66 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[67,68,69]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracolumbar spine and sacroiliac joints. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracolumbar spine and sacroiliac joints and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Chicas, a causal link between the subject incident and claimed thoracic, lumbar, and sacral biomechanical failures cannot be made.

Personal Tolerance Values

Ms. Chicas testified that she worked as a home health aide for Kaiser Permanente. Her job required her to give baths, assist ambulation, take vitals, and measure range of motion. She was capable of cleaning her house, walking 2 husky dogs, hike, garden, and play with her grandson. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Chicas and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Chicas's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Chicas using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On May 23, 2015, Ms. Estella Chicas was the seat-belted driver of a 2005 Scion xA that was stopped on South Meyers Road in Oregon City, Oregon, when the subject Scion was contacted in the rear at low speed by a 2001 Saturn L200.
2. The severity of the subject incident was below 12.4 miles-per-hour with an average acceleration less than 3.8g.
3. The acceleration experienced by Ms. Chicas was within the limits of human tolerance and comparable to that experienced during various daily activities.

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67 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

68 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

69 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Chicas's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Chicas's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Chicas's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Chicas's claimed sacroiliac joint biomechanical failures. As such, a causal relationship between the subject incident and the sacroiliac joint biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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March 28, 2018

Scott MacLaren, Esquire
Maloney Lauersdorf Reiner, PC
1111 E. Burnside Street, Suite 300
Portland, OR 97214

Re: *Herrera, Juan v. Colette Walters*
File No.: 3080-115
ARCCA Case No.: 5383-001

Dear Mr. MacLaren:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Juan Herrera. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.
2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.
3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.
4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.
5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

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Incident Description:

According to the available documents, on November 13, 2016, Mr. Juan Herrera was the seat-belted front right passenger of a 2011 Toyota Camry traveling eastbound on Market Street in Salem, Oregon. Ms. Colette Walters was the driver of a 2002 Honda Accord traveling immediately behind the subject Toyota. While the subject Toyota was stopped in the left turn lane, contact was made between the rear of the subject Toyota and the front of the incident Honda.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Twelve (12) color photographic reproductions of the subject 2011 Toyota Camry
- Thirteen (13) color photographic reproductions of the incident 2002 Honda Accord
- Estimate for repairs of the subject 2011 Toyota Camry [November 29, 2016]
- Complaint, *Juan Herrera vs. Colette J. Walters* [December 19, 2017]
- Recorded statement transcript of Colette Walters [February 21, 2017]
- Recorded statement transcript of Juan Onesimo Herrera-Vidana [February 22, 2017]
- Medical Records pertaining to Juan Herrera
- VinLink data sheet for the subject 2011 Toyota Camry
- Expert AutoStats data sheets for a 2011 Toyota Camry
- VinLink data sheet for the incident 2002 Honda Accord
- Expert AutoStats data sheets for a 2002 Honda Accord
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Mr. Herrera claims were caused by the subject incident on November 13, 2016;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2011 Toyota Camry;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury*. SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities. *Annual Review of Biomedical Engineering*, 3(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

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3. Determine Mr. Herrera's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Mr. Herrera's personal tolerances in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Mr. Herrera attributes the following biomechanical failures as a result of the subject incident:

3½ - 20

- Cervical Spine
  - Sprain/strain
- Thoracic Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair documents of the subject Toyota Camry, and photographic reproductions of the incident Honda Accord, in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject Toyota Camry reported damage to the rear bumper cover. The photographs depicted bolt holes and paint cracking to the rear bumper cover (Figure 1). There was no significant crush to the rear components of the vehicle, and the rear bumper cover remained in proper alignment with the tail gate and quarter panels.

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11 Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

12 Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

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Figure 1: Reproductions of photographs of the subject 2011 Toyota Camry

The photographs of the incident Honda depicted multiple paint gouges and scrapes to the front bumper cover, which was also dented on the right and left corners (Figure 2). The lower grille was fractured, and the front license plate was bent. Considering the damage to the rear of the subject Toyota, and the contact pattern between the two vehicles during the subject incident, the crush to the right and left side of the Honda's front bumper were concluded to be pre-existing and unrelated to the subject incident. Ms. Walters also stated that the Honda had prior damage.

Figure 2: Reproductions of photographs of the incident 2002 Honda Accord

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Toyota Camry, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[13] The IIHS tested a model year 2006-2011 Toyota Camry in a 6.2 mile-per-hour rear impact into a full-width barrier.[14] The test Toyota sustained damage to the left and right quarter panels, rear body panel, rear bumper, rear bumper cover, and deck lid. The primary damage to the subject Toyota was to the rear bumper cover. Thus, because the test Toyota Camry in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident. Accounting for restitution, the subject Toyota experienced a Delta-V of less than 8.0 miles-per-hour.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with an 8.0 mile-per-hour Delta-V is 2.4g.[15,16,17,18] By the laws of physics, the average acceleration experienced by the subject Toyota Camry in which Mr. Herrera was seated was less than 2.4g. This analysis is consistent with an energy crush analysis to the front of a 2002 Honda Accord.[19,20,21,22]

The acceleration experienced due to gravity is 1g. This means that Mr. Herrera experiences 1g of loading while in a sedentary state. Therefore, Mr. Herrera experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during

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13 Siegmund, G.P., et al., (1996) *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

14 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2007 Toyota Camry, May 2007.

15 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

16 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

17 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

18 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

19 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

20 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

21 EDCRASH, Engineering Dynamics Corp.

22 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

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daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[23] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Mr. Herrera's medical records indicated he was 70 inches in height, weighed approximately 238 lbs., and was 25 years old at the time of the subject incident. Mr. Herrera indicated that he was belted, unaware of the oncoming incident, and facing forward at the time of the subject incident. He stated that the *"rear bumper was a little bit dented in and it had a hole in it"*. In the medical records, Mr. Herrera indicated that the incident vehicle was traveling 10 miles-per-hour, and the subject Toyota did not have head restraints. However, another entry in the medical records states that the incident Honda was traveling 15 miles-per-hour, and Mr. Herrera's head contacted the head restraint that was positioned at the middle of his neck.

The laws of physics dictate that when the subject Toyota Camry was contacted in the rear, it would have been pushed forward causing Mr. Herrera's seat to move forward relative to his body. This motion would result in Mr. Herrera moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Mr. Herrera's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Mr. Herrera was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Mr. Herrera's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Herrera would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Herrera was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[24,25]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

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23 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

24 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash.* (No. 670919). SAE Technical Paper.

25 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck.* (No. 710855). SAE Technical Paper.

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If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

In a rear impact that produces motion of the subject vehicle, the Toyota Camry would be pushed forward and Mr. Herrera would have moved rearward relative to the vehicle, until his motion was stopped by the seatback and seat bottom. Examination of an exemplar Toyota Camry revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.75 inches in the full down position, and 34.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Mr. Herrera revealed he would have a normal seated height of 35.3 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Mr. Herrera's cervical spine would have undergone only a subtle degree of the characteristic response phases.[26] The load would have been applied predominantly horizontal to his cervical spine and minimized relevant cervical loads.[27] The cervical loads were within physiologic limits and Mr. Herrera would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[28,29,30]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[31,32,33,34,35] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the

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26 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

27 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

28 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

29 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms. (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

30 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

31 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

32 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

33 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

34 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

35 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

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seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[36] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[37,38,39,40] The available documents reported Mr. Herrera was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[41]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Herrera cannot be made.

Thoracic and Lumbar Spine

During an event such as the subject incident, the thoracic and lumbar spine of Mr. Herrera is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Mr. Herrera's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

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36 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine, 29*(9), 979-987.

37 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation, 42*, 410

38 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation, 42*, 25-30

39 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact*, 233-248.

40 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering, 39*(2), 766-776.

41 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living.* (No. 2006-01-0247). SAE Technical Paper

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[42,43,44,45] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[46] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs, which measured spinal response to rear impact accelerations at severities greater than the subject incident.[47,48] Mr. Herrera's thoracic and lumbar spine would not have been exposed to any loading or motion outside of the range of his personal tolerance levels.[49,50,51,52,53]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[54,55,56,57] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[58,59] Peer-reviewed technical literature and learned treatises have

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42 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 6(6), 366-375.

43 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

44 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

45 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

46 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, 5, 22-26.

47 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

48 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

49 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

50 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

51 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, 7(3), 184-191.

52 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, 16(7), 549-559.

53 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

54 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, 44(8), 781-794.

55 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, 27(8), 754-758.

56 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, 46(3), 511-514.

57 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

58 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, 42, 410.

59 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[60] According to the available documents, Mr. Herrera was capable of performing daily activities. A segmental analysis of Mr. Herrera demonstrated that as he lifted objects during daily tasks, the forces applied to his lower spine would have been comparable to or greater than those during the subject incident.[61,62,63]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Herrera, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

Personal Tolerance Values

The available records indicate that Mr. Herrera worked as a painter, and was capable of twisting, lifting heavy materials and drop cloths, and climbing ladders. Daily activities can produce greater movement, or stretch, to the soft tissues of Mr. Herrera and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Herrera's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Herrera using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On November 13, 2016, Mr. Juan Herrera was the seat-belted front right passenger of a 2011 Toyota Camry that was stopped on Market Street in Salem, Oregon, when the subject Toyota was contacted in the rear at low speed by a 2002 Honda Accord.
2. The severity of the subject incident was below 8.0 miles-per-hour with an average acceleration less than 2.4g.

60 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, 29(20), 2319-2329.
61 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.
62 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.
63 Chaffin, DB, Andersson, GBJ, Martin, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

ARCCA

3. The acceleration experienced by Mr. Herrera was within the limits of human tolerance and comparable to that experienced during various daily activities.

4. The forces applied to the subject vehicle during the subject incident would tend to move Mr. Herrera's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Herrera's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Herrera's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This report is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

ARCCA

I, Bradley Probst, declare under the penalty of perjury under the laws of the State of Washington that the following is true and correct:

1. I am over the age of 18 years, I am competent to testify, and have personal knowledge of the facts contained herein in this declaration.

2. I declare that the attached biomechanical report was prepared by myself and is true and correct to the best of my knowledge.

3. The opinions and conclusions stated herein are stated on a more-probable-than-not basis and to a reasonable degree of engineering certainty.

SIGNED

IN THE SUPERIOR COURT OF THE STATE OF WASHINGTON
IN AND FOR THE COUNTY OF CLARK

SANDY MONDRAGON, Plaintiff, v. LAURA KOFOED, Defendant.	No.: 18-2-05034-4 DECLARATION OF BRADLEY PROBST, MSBME

I, Bradley Probst, MSBME, do hereby declare and say as follows:

1. This Declaration is based upon my own personal knowledge, information and belief. I am over the age of 18 and competent to testify as to the information stated herein.

2. I am a biomechanist employed by ARCCA Incorporated. I have been qualified to give testimony in courts on issues related to biomedical and biomechanical science in the State of Washington and other places around the country.

3. I was retained by Defendant to review information regarding the July 29, 2016 motor vehicle accident involving Defendant and Plaintiff and determine the forces experienced by the plaintiff.

4. Attached as Exhibit "A" to this Declaration, and incorporated herein, is a true and correct copy of the June 14, 2018 report I prepared following my review of the records.

Douglas Foley & Associates, PLLC
13115 NE 4th Street, Suite 260
Vancouver, WA 98684
Telephone: 360.883.0636

5. Attached as Exhibit "B" to this Declaration, and incorporated herein, is a true and correct copy of my current CV.

6. I certify that this report is true and accurate as written. It is submitted in lieu of my testimony at the arbitration in this matter.

I DECLARE UNDER PENALTY OF PERJURY UNDER THE LAWS OF THE STATE OF WASHINGTON THAT THE FOREGOING IS TRUE AND CORRECT.

Signed at Seattle, Washington on June 13th, 2018.

Bradley Probst, MSBME

187/6041

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June 14, 2018

Kevin Sampson, Esquire
Douglas Foley & Associates, PLLC
13115 NE 4th Street
Park Tower Five
Suite 260
Vancouver, WA 98684

Re: *Mondragon, Sandy v. Laura Kofoed*
ARCCA Case No.: 3104-130

Dear Mr. Sampson:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Sandy Mondragon. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

Exhibit A to Declaration of Probst

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on July 29, 2016, Ms. Sandy Mondragon was the seat-belted driver of a 2010 Toyota Prius on the SR 500 exit ramp towards NE Andresen Road in Vancouver, Washington. Ms. Laura Kofoed was the driver of a 2010 Toyota Prius traveling immediately behind the subject Toyota. While the subject Toyota was stopped in traffic preparing to turn right, contact was made between the rear of the subject Toyota Prius and the front of the incident Toyota Prius.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. E570640*
- Seventeen (17) color photographic reproductions of the subject 2010 Toyota Prius
- One (1) color photographic reproduction of the incident 2010 Toyota Prius
- Nineteen (19) color photographic reproductions of the subject incident scene
- Preliminary Estimate for the subject 2010 Toyota Prius [August 8, 2016]
- Estimate for repairs of the subject 2010 Toyota Prius [August 12, 2016]
- Supplement 1 for repairs of the subject 2010 Toyota Prius [September 20, 2016]
- Complaint for Personal Injuries, *Sandy Mondragon vs. Laura Kofoed* [October 6, 2017]
- Answers and Affirmative Defenses, *Sandy Mondragon v. Laura Kofoed* [February 19,2018]
- Deposition transcript of Sand Mondragon, *Sandy Mondragon v. Laura Kofoed* [June 4, 2018]
- Medical Records pertaining to Sandy Mondragon
- VinLink data sheet for the subject 2010 Toyota Prius
- VinLink data sheet for the incident 2010 Toyota Prius
- Expert AutoStats data sheets for a 2010 Toyota Prius
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

1. Identify the biomechanical failures that Ms. Mondragon claims were caused by the subject incident on July 29, 2016;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2010 Toyota Prius;
3. Determine Ms. Mondragon's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Mondragon's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Mondragon attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Soft-tissue biomechanical failure
- Thoracic Spine
  - Soft-tissue biomechanical failure
- Lumbar Spine
  - Soft-tissue biomechanical failure
- Bilateral Shoulder
  - Soft-tissue biomechanical failure

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair documents of the subject 2010 Toyota Prius, and photographic reproductions of the incident 2010 Toyota Prius, in association with accepted scientific methodologies. [11,12]

The photographic reproductions of the subject Prius depicted a scrape/gouge to the left and right sides of the rear bumper cover (Figure 1). There was a small dent in the right side of the rear bumper cover, and a small tear to the upper right corner of the absorber. There was no damage to the reinforcement bar, quarter panels, lift gate, or tail lamps.

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[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 2010 Toyota Prius

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photographs and geometric measurements of the subject 2010 Toyota Prius revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 miles per hour (mph) flat barrier impact to the rear of an exemplar Toyota Prius would result in significant and visibly noticeable crush across the entirety of the subject Prius' rear structure, with a residual crush of 5.0 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mph Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural crush to the entire rear of the subject Toyota Prius indicates a collision resulting in a Delta-V significantly below 10 mph.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.
14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.
15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.
16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.
17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.
18 EDCRASH, Engineering Dynamics Corp.
19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

Further, the Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Toyota Prius, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[20] The IIHS tested an exemplar 2010 Toyota Prius in a 6.2 mph rear impact into a flat barrier.[21] The test Toyota sustained damage to the storage compartment, tailgate shell, rear body panel, computer module, sill plate, left and right tail lamps, rear bumper cover, rear bumper mounting bracket, rear energy absorber, and R lower rear spoiler. The primary damage to the subject Toyota Prius was to the rear bumper cover and absorber. Accounting for restitution, the subject Prius experienced a Delta-V more consistent with 8.0 mph.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mph Delta-V is 3.0g, and the average acceleration associated with a 8.0 mph Delta-V is 2.4g.[22,23,24,25] By the laws of physics, the average acceleration experienced by the subject Toyota Prius in which Ms. Mondragon was seated was less than 3.0g and more consistent with 2.4g.

The acceleration experienced due to gravity is 1g. This means that Ms. Mondragon experiences 1g of loading while in a sedentary state. Therefore, Ms. Mondragon experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[26] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Mondragon's medical records indicated she was 61 inches in height, weighed approximately 190 lbs., and was 26 years old at the time of the subject incident. Ms. Mondragon testified that she was looking left for traffic, and her foot was on the brake. She further testified, *"I was wearing my seat belt, so I immediately felt the jerk forward, my seat belt tightening"*.

The laws of physics dictate that when the subject Toyota Prius was contacted in the rear, it would have been pushed forward causing Ms. Mondragon's seat to move forward relative to her body. This motion would result in Ms. Mondragon moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Mondragon's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Mondragon was wearing the available three point restraint. Any rebound would have been within the range of protection

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20 Siegmund, G.P., et al., (1996) Us*ing Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

21 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2008 Toyota Prius, September 2008.

22 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

23 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

24 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

25 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

26 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

afforded by the available restraint system and coupled Ms. Mondragon's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Mondragon would have been limited to well within the range of normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Mondragon was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[27,28]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. A soft-tissue biomechanical failure refers to a sprain/strain type failure. A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

In a rear impact that produces motion of the subject vehicle, the subject Toyota Prius would be pushed forward and Ms. Mondragon would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. The IIHS performs simulated rear impact testing on anthropometric test devices (ATDs) to evaluate seatback safety. Examination of the front seat from an exemplar Toyota Prius revealed that a seated 50th percentile male ATD was well protected during testing.[29] The seatback in the dynamic test, performed at an average impact acceleration of 4.8g, received the highest overall rating. Performing an anthropometric regression of Ms. Mondragon revealed she would have a normal seated height of 31.7 inches, approximately 3 inches shorter than

27 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.
28 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.
29 Insurance Institute for Highway Safety, 2010 Toyota Prius Rear Impact Seat Test, *Test ID SER09016*, June 24, 2009.

the 50th percentile male ATD. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Mondragon's cervical spine would have undergone only a subtle degree of the characteristic response phases.[30] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[31] The cervical loads were within physiologic limits and Ms. Mondragon would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[32,33,34]

Several researchers have conducted human volunteer rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[35,36,37,38,39] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[40] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[41,42,43,44] The available documents reported

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30 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

31 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

32 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

33 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

34 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

35 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

36 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

37 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

38 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

39 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

40 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

41 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

42 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

43 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

44 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

Ms. Mondragon was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[45]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Mondragon cannot be made.

Thoracic and Lumbar Spine

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Mondragon is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Mondragon's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[46,47,48,49] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[50] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[51,52] Ms. Mondragon's thoracic and lumbar

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45 Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

46 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

47 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

48 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

49 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

50 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

51 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

52 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[53,54,55,56,57]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[58,59,60,61] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[62,63] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[64] According to the available documents, Ms. Mondragon was capable of performing daily activities. A segmental analysis of Ms. Mondragon demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[65,66,67]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Mondragon, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

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53 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

54 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

55 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

56 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

57 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

58 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

59 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

60 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

61 Morris, J.M., Lucas, D.B., Bresler, B., (1961). “Role of the Trunk in Stability of the Spine.” The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

62 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

63 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Lumbar and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

64 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

65 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

66 Morris, J.M., Lucas, D.B., Bresler, B., (1961). “Role of the Trunk in Stability of the Spine.” The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

67 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

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Bilateral Shoulder

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[68] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[69]

Ms. Mondragon's torso would have moved rearward relative to the subject vehicle's interior, which would have been supported and constrained by the seatback.[70,71,72,73] The seatback would have distributed any loading across her entire back and shoulders. Any rebound would have been limited by the seat belt which would have engaged Ms. Mondragon's bony left clavicle and pelvis. The restraint provided by the seat belt restraint and seatback were such that any motion of Ms. Mondragon's shoulders would have been limited to well within the range of normal physiological limits.

The records indicate Ms. Mondragon was capable of kayaking and lifting *"heavy stuff"*. Common activities would directly load Ms. Mondragon's shoulders multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[74,75,76,77] These data demonstrate that the shoulder forces and accelerations of the subject incident did not exceed Ms. Mondragon's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the

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68 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

69 Braun, S., Kokmeyer, D., and Millett, P.J., et al., (2009). *Shoulder Injuries in the Throwing Athlete*. Journal of Bone and Joint Surgery 91: 966-978.

70 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

71 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.

72 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

73 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions.* (No. 2010-01-0067). SAE Technical Paper.

74 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

75 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

76 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

77 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

subject incident and the reported bilateral shoulder biomechanical failures of Ms. Mondragon cannot be made.

Personal Tolerance Values

Ms. Mondragon testified that her hobbies included hiking, running, and kayaking. She further testified she was capable of lifting, and indicated she could complete her job duties as a case specialist. Daily activities can produce greater movement, or stretch, to the soft tissues of Ms. Mondragon and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Mondragon's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Mondragon using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On July 29, 2016, Ms. Sandy Mondragon was the seat-belted driver of a 2010 Toyota Prius that was stopped on the SR 500 exit ramp in Vancouver, Washington, when the subject Toyota was contacted in the rear at low speed by a 2010 Toyota Prius.
2. The severity of the subject incident was below 10 mph with an average acceleration less than 3.0g, and more consistent with 8.0 mph with an average acceleration of 2.4g.
3. The acceleration experienced by Ms. Mondragon was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Mondragon's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mondragon's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mondragon's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Mondragon's claimed bilateral shoulder biomechanical failures. As such, a causal relationship between the subject incident and the bilateral shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

ARCCA INCORPORATED

BRADLEY W. PROBST, M.S.B.M.E.
PROFESSIONAL BIOGRAPHICAL OUTLINE

BACKGROUND
Mr. Probst earned a B.S. in Mechanical Engineering at University of Louisiana, Lafayette, Louisiana, and an M.S. in Biomedical Engineering at Tulane University, New Orleans, Louisiana. For his Ph.D. research at Tulane, Mr. Probst developed the most advanced kinematic model of the human cervical spine known to date. This unique model will be used to make technological advances to Naval pilot ejection and recovery systems. In addition, Mr. Probst has also done advanced course work in the fields of biomaterials, materials engineering, biosolid mechanics, mechanisms of bodily functions, and advanced finite element analysis. He has also lectured extensively and shared teaching responsibilities for courses in biomedical engineering and design and analysis at Tulane University.

As a biomedical consultant for a national accident investigation firm and while a student, Brad gained valuable experience in forensic analysis while working on a university project to research soft tissue injury caused by dynamic inertial loading.

While investigating and presenting work on bone morphology, his focus was the proper use of computation modeling as it related to bone material property identification. His significant contributions led to important developments in the field of bone mechanics and response of living bone to stress and disease.

SUMMARY OF EXPERIENCE
- Developed his skills in mechanical engineering while acting as project engineer at a petrochemical facility, where he was responsible for several multimillion-dollar expansion and renovation projects
- Pursued graduate research on a federally funded project to investigate spinal trauma and human head and neck tolerances to dynamic impact loadings
- Performed finite element analysis, computer modeling, material testing and data analysis
- Used advanced numerical methods for model validation
- Operated state-of-the-art high-speed computers to develop his calibrated model and to validate biofidelity
- Created an accurate biofidelic model of the kinematic response of the human head and neck during any general 3D acceleration through the development of a finite element model. The conclusions and results of this important project will be used to make technological advances toward improving the safety of pilots during ejection and major recovery system improvements
- Uses his biomedical and mechanical engineering skills to analyze the relationship of crash injuries to crash forces, occupant kinematics, and human tolerance
- Uses forensic investigation and accident reconstruction techniques to develop injury mitigation devices

Exhibit B to Declaration of Probst

AREAS OF SPECIALTY

- Biomechanical Consulting
- Human Injury Tolerance
- Vehicular Accident Reconstruction
- Impact and Inertial Trauma Analysis
- Injury Mechanism and Mitigation Analysis
- Slip and Fall Analysis

ACADEMIC BACKGROUND

- Tulane University, New Orleans, LA, Ph.D. Candidate, Biomedical Engineering
- Tulane University, New Orleans, LA, M.S., Biomedical Engineering, 1996
- University of Louisiana, Lafayette, LA, B.S., Mechanical Engineering, 1988

PROFESSIONAL EXPERIENCE

January 2000 – Present | ARCCA, Incorporated | Senior Biomechanist

- Specializes in injury analysis, injury mechanism determination and crash kinematics
- Practices biomechanics to explore the cause, nature and severity of injuries
- Utilizes medical records, testing, computer modeling and his extensive knowledge of human injury tolerance to determine whether a claimed injury is consistent with a specific set of actions or exposure to a specific accident environment

1995 – 2000 | Tulane University | Research Assistant

- Pursued graduate research on a spinal trauma investigation and analysis project funded by the Office of Naval Research. His position was secured, fully funded and compensated through competitive selection
- Performed finite element analysis, computer modeling, material testing, and data analysis to develop biofidelic human cervical spine analog
- Utilized advanced numerical methods for model validation
- Proposed conclusions and research results that will be used to implement technological advancements in naval pilot ejection and recovery systems

1997 – 1999 | Unified Investigations & Sciences, Inc. | Biomechanical Consultant

- Performed forensic analysis of soft tissue injury from mild impact in automotive accidents
- Determined impact levels through vehicular accident reconstruction, and compared findings to determine injury causation and severity
- Presented written conclusions to clients and provided expert testimony relative to his findings

May 1995 – 1999 | Tulane University | Teaching Assistant

- Selected by faculty mentor to assist with and share teaching responsibilities for courses such as Statics, Introduction to Biomedical Engineering and Design and Analysis
- Collaborated with mentor to plan lectures
- Prepared of course material
- Presented lectures

ARCCA

1988 – 1995 | Wink Engineering | Mechanical/Project Engineer

- Managed and was responsible for several multimillion-dollar expansion and renovation projects at a petrochemical facility
- Directed and performed environmental remediation (air and water)
- Recommended and implemented improvements to waste water treatment systems

PROFESSIONAL AFFILIATIONS

- Association for the Advancement of Automotive Medicine
- Society of Automotive Engineers (SAE)
- American Society of Safety Engineers (ASSE)
- American Society of Mechanical Engineers (ASME)

PUBLICATIONS

Probst, B, R. Anderson, G. Harris, R. Hart. (2007). *A Three-Dimensional Nonlinear Kinematic Finite Element Model of the Human Cervical Spine Under Dynamic Inertial Loading.* American Society of Biomechanics Biomechanics Symposium 2007, Stanford University: ASB.

Cantor, A., M. Markushewski, L. D'Aulerio, B. Benda, D. Eisentraut, **B. Probst**, L. Sicher. (2007). *Seat Design: A Risk Benefit Approach*. ASSE.

Probst, B. (Presenter). (2007). *Industrial vs. Academic Perspectives on Bioengineering Education*. ASME Summer Bioengineering Conference. Keystone, CO: ASME.

Probst, B., R. Anderson, T. Hart, G. Harris, S. Guccione. (2007). *A Three-Dimensional Nonlinear Kinematic Finite Element Model of the Human Cervical Spine Under Dynamic Inertial Loading.* American Society of Biomechanics Northwest Biomechanics Symposium 2007, Eugene, Oregon: ASB.

Markushewski, M., Gushue, D., **Probst, B.**, Coward, C., (2007). *When Driver Safety Fails—Then What? Vehicular Accident Analysis: The Big Picture*. ASSE.

Gushue, D.L., Joganich, T., **Probst. B. W.**, Markushewski, M. (2007). *Biomechanics for Risk Managers—Analysis of Slip, Trip & Fall Injuries*. ASSE.

Gushue, D., **B. Probst**, et al. (2006). *Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts*. Safety 2006, Seattle, WA, ASSE.

Benda, B. J., L. D'Aulerio, A. Cantor, M. L. Markushewski, **B. Probst**, et al. (2006). *Performance of Automotive Seat Belts During Inverted (-Gz) Rollover Drop Tests*. Icrash 2006—International Crashworthiness Conference, Athens, Greece, University of Bolton.

Coleman, J.C., **Probst, B.W.**, Roberts, M.D., and Hart, R.T. (1999). *Meshes Based On Cube-Shaped Finite Elements Do Not Converge: Quadratic Tetrahedral Elements Are An Alternative. Proceedings of the 1999 Summer Bioengineering Conference (ASME)* Big Sky, MT, June 1999. (pp. 329-230) New York: ASME.

Coleman, J.C., **Probst, B.W.**, Roberts, M.D., and Hart, R.T. (1998). *Investigating the Convergence Behavior of Voxel-Based Finite Element Meshes. Proceedings of the 7th Annual Symposium on Computational Methods in Orthopaedic Biomechanics*, Anaheim, CA, February 1998. Chicago: Orthopaedic Research Society (ORS).

COURSE INSTRUCTION

- *Slip/Trip/Falls*, Rocky Mountain IASIU Chapter, Denver, CO. May 7, 2009
- *Biomechanics*, Puget Sound Special Investigators, Seattle, WA. July 30, 2009
- *Slip/Trip/Falls*, Las Vegas IASIU Chapter, Las Vegas, NV. December 7, 2009
- *Low Speed Impacts*, Oregon IASIU Chapter, Portland, OR. May 4, 2010
- *Slip/Trip/Falls*, Oregon IASIU Chapter, Portland, OR. Oct 7, 2011
- *Biomechanics*, Hawaii RIMS Chapter, Honolulu, HI. September 15, 2011
- *Determining Injury Causation*, Alaska RIMS Chapter, Anchorage, AK. October 19, 2011
- *Biomechanics*, OR RIMS Chapter, Portland, OR. June 20, 2013
- *Determining Injury Causation*, Los Angeles RIMS Chapter, September 17, 2014

OTHER PROFESSIONAL ACTIVITIES

Judge at the Edmonds Annual Hot Autumn Nites Car Show, Edmonds, WA, September 6, 2008 sponsored by the Greater Edmonds Chamber of Commerce

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June 15, 2018

Gavin Radkey, Esquire
Wood, Smith, Henning & Berman, LLP
520 Pike Street
Suite 1525
Seattle, WA 98101

Re: *Willis, Eric v. MV Transportation Technologies, Inc. and Walter David Boyles*
ARCCA Case No.: 4581-021

Dear Mr. Radkey:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Eric Willis. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry. [1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

Incident Description:

According to the available documents, on February 13, 2015, Mr. Eric Willis was the seat-belted driver of a 2015 Toyota Tacoma traveling in Redmond, Washington. Mr. Walter David Boyles was the driver of a 2011 Ford Fusion traveling through the same intersection as the subject Toyota. As the subject Toyota was travelling through an intersection, contact was made between the right side of the subject Toyota and the front of the incident Ford. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- MV Transportation, Inc. Vehicular Accident Report
- Three (3) color photographic reproductions of the subject incident location
- Two (2) color photographic reproductions of the subject 2015 Toyota Tacoma
- Seventeen (17) black and white photographic reproductions of the subject 2015 Toyota Tacoma
- Four (4) color photographic reproductions of the incident 2011 Ford Fusion and 2015 Toyota Tacoma
- Final Bill for repairs of the subject 2015 Toyota Tacoma [March 6, 2015]
- Final Bill for repairs of the incident 2011 Ford Fusion [March 2, 2015]
- Complaint, *Eric Willis v. M.V. Transportation Technologies Inc. et al* [August 31, 2017]
- Independent Medical Evaluation Report from Dr. Steven Klein [June 6, 2018]
- VinLink data sheet for the subject 2015 Toyota Tacoma
- Expert AutoStats data sheets for a 2015 Toyota Tacoma
- VinLink data sheet for the incident 2011 Ford Fusion
- Expert AutoStats data sheets for a 2011 Ford Fusion
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

7 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

8 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

9 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

10 Whiting, W.C. and Zernicke, R.F., (1998) Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

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1. Identify the biomechanical failures that Mr. Willis claims were caused by the subject incident on February 13, 2015;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the vehicle Mr. Willis was occupying;
3. Determine Mr. Willis's kinematic response within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident.
5. Evaluate Mr. Willis's personal tolerance in the context of his pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and his reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

According to the available documents, Mr. Willis attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Lumbar Spine
  - Sprain/strain
- Left Shoulder
  - Sprain/strain

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2015 Toyota Tacoma and the incident 2011 Ford Fusion in association with accepted scientific methodologies. [11,12]

The repair documentation for the subject Toyota reported the damage to the right caution label, right door with strip, seam seal door, right door shell, right upper hinge, right lower hinge, transfer right rear door fixed glass, right side panel, set back box assembly, right protector, right lower molding, right stone guard, right lower molding clip, right lower molding grommel, right wheelhouse liner, grommet, right nameplate, right scuff plate front/rear, right rear wheel, and spray stone guard. Additionally, it was reported that the subject Toyota required a wheel alignment, balance and mount,

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

as well as a pull to the rocker, door opening, right side panel, and right rocker panel. The photographs depicted residual crush to the lower portion of the right panel (Figure 1).

Figure 1: Reproductions of photographs of the subject 2015 Toyota Tacoma

The repair estimate for the 2011 Ford Fusion indicated damage to the front bumper cover, absorber, impact bar, bumper grille/surround, valance, left/right bezel, left/right insert panel, left side retainer, left impact bar stud, license bracket, right side retainer, grille mount panel pin, left/right headlamp assembly, left side marker lamp, and lower deflector rivet. Additionally, the incident Ford required alignment to the right fender and hood. The photographs depicted the front bumper cover detached from the vehicle, except for the far right corner (Figure 2).

Figure 2: Reproductions of photographs of the incident 2011 Ford Fusion and subject 2015 Toyota Tacoma

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject Toyota Tacoma revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 miles per hour (mph) flat barrier impact to the passenger side of an exemplar Toyota Tacoma would result in significant and visibly noticeable crush, with a residual crush of 5.5 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mph Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural crush to the entire ear of the subject Toyota indicates a collision resulting in a Delta-V significantly below 10 mph. This analysis is also consistent with an energy-based crush analyses to the front of the incident Ford Fusion.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mph impact is 3.0g.[20,21,22,23] By the laws of physics, the average acceleration experienced during the subject impact by the subject Toyota in which Mr. Willis was seated was significantly less than 3.0g.

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that a person experiences 1g of loading while in a sedentary state. Therefore, Mr. Willis experience an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[24] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity.* (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment.* (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3.* (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions.* (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V.* (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

20 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration.* (No. 2000-01-0880). SAE Technical Paper.

21 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions.* (No. 980298). SAE Technical Paper.

22 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts.* (No. 970120). SAE Technical Paper.

23 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations.* (No. 2001-01-0891). SAE Technical Paper.

24 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

Kinematic Analysis:

The laws of physics dictate that when the subject Toyota Tacoma was contacted in the right side, it would have been pushed left causing Mr. Willis's seat to move leftward relative to his body. The laws of physics and results from previous studies[25,26] dictate that Mr. Willis would have tended to move rightward relative to the vehicle's interior. This motion would have been controlled and supported by the friction generated at his seat bottom, the center console, and the three-point restraint. Specifically, the three-point restraint would have locked during the subject incident had the acceleration exceeded 0.7g and limited any potential forward body excursion.[27] Provided the low accelerations of the subject incident, and the supports described, the bodily response of Mr. Willis would have been limited to well within normal physiological limits.

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Mr. Willis was well within the limits of human tolerance and well below the acceleration levels that he likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link his reported biomechanical failures and the subject incident.[28,29]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failures is determined by addressing two issues or questions:

1. Did the subject incident load the body in a <u>manner</u> known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient <u>magnitude</u> to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

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25 Chandler, R.F., and Christian, R.A. (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

26 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

27 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

28 Mertz, H. J. and L. M. Patrick (1967). Investigation of The Kinematics of Whiplash During Vehicle Rear-End Collisions (SAE670919). Warrendale, PA, Society of Automotive Engineers.

29 Mertz, H. J. and L. M. Patrick (1971). Strength and Response of The Human Neck (SAE710855). Warrendale, PA, Society of Automotive Engineers.

Cervical Spine

According to the medical records and available documents, Mr. Willis attributes a cervical sprain/strain to the subject incident.

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

As described previously, a side impact would have caused the subject Toyota Tacoma to move left, causing Mr. Willis's seat to move left relative to his body. Mr. Willis would have moved rightward relative to the vehicle's interior.[30,31] This motion would have been supported and constrained by the three-point restraint and seat bottom friction of the subject Toyota. Mr. Willis's cervical spine would have been subjected to a controlled degree of flexion and lateral bending during the subject incident. That is, head flexion is anatomically limited by chin-to-chest contact while lateral bending is limited by head-to-shoulder contact.[32]

Many research studies support these above conclusions. Human volunteers have been exposed to frontal and lateral impact accelerations at levels comparable to, and greater than that of the subject incident.[33,34,35,36,37,38,39,40,41,42,43] Participants moved toward the point of impact, rightward in this case, while their response was controlled by the three-point restraint, seat structures, and vehicle interior components. None of the volunteers reported cervical trauma in response to this testing. Further research has exposed cadavers to impact accelerations within the biomechanical failure range.[44,45] These results demonstrated that the accelerations during the subject incident were maintained well

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30 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

31 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

32 Mertz, H.J., and Patrick, L.M., (1971) Strength and Response of the Human Neck, (SAE 710855). Warrendale, PA, Society of Automotive Engineers.

33 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

34 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

35 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

36 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

37 Matsushita, T., Sato, T.B., Hirabayashi, K., et al. (1994). X-ray Study of the Human Neck Motion Due to Head Inertia Loading (SAE 942208). Warrendale, PA. Society of Automotive Engineers.

38 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

39 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

40 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

41 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

42 Fugger, TF, et al (2002) Human Occupant Kinematics in Low Speed Side Impacts (SAE 2002-01-0020). Warrendale, PA. Society of Automotive Engineers.

43 Bailey, M.N., Wong, B.C., and Lawrence, J.M. (1995) Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

44 Ivancic, P.C., Ito, S., Panjabi, M.M., et al. (2005). "Intervertebral Neck Injury Criterion for Simulated Frontal Impacts." Traffic Injury Prevention 6: 175-184.

45 Pearson, A.M., Panjabi, M.M., Ivancic, P.C., et al. (2005). "Frontal Impact Causes Ligamentous Cervical Spine Injury." Spine 30(16): 1852-1858.

within human tolerance as none of the cadaveric testing resulted in cervical trauma at acceleration levels consistent with the subject incident. The accelerations during the subject incident were maintained within published guidelines for safe human exposure to frontal and lateral impact accelerations.[46] In addition, these studies demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

As stated previously, the human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. In recent papers by Ng et al.,[47,48] accelerations of the head and spinal structures were measured during activities of daily living. Peak accelerations of the head were measured to be an average 2.38g for sitting quickly in a chair, while the measured accelerations for a vertical leap were 4.75g. Research by Funk et al.[49] demonstrated that a simple head shake or a self-inflicted hand strike to the head induces accelerations comparable to or greater than the subject incident. Mr. Willis performed daily activities without biomechanical failure prior to the subject incident. These activities would have generated cervical forces that were comparable to and greater than those of the subject incident.[50,51,52,53] These data demonstrate that the cervical forces of the subject incident did not exceed Mr. Willis's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Mr. Willis cannot be made.

Lumbar Spine

According to the medical records and available documents, Mr. Willis attributes lumbar sprain/strain to the subject incident. As stated previously, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

In this type of collision, the motion of Mr. Willis's lumbar spine would have been well supported and constrained. Provided sufficient energy to overcome Mr. Willis's muscle reaction forces, his body would have moved rightward relative to the Toyota's interior. As described previously, Mr. Willis stated he was wearing the available three-point restraint. The three-point restraint would have locked during the subject incident and limited any forward body excursion that may have occurred.[54] The

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46 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

47 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "Thoracic and Lumbar Spine Accelerations in Everyday Activities", Biomed Sci Instrum, 42:410-415.

48 Ng, T.P., Bussone, W.R., Duma, S.M., Kress, T.A., (2006) "The Effect of Gender of Body Size on Linear Acceleration of the Head Observed During Daily Activities", Rocky Mountain Bioengineering Symposium & International ISA Biomedical Instrumentation Symposium, (2006) 25-30.

49 Funk, J.R., Cormier, J.M., et al., (2007) "An Evaluation of Various Neck Injury Criteria in Vigorous Activities." International Research Council on the Biomechanics of Impact: 233-248.

50 Ng, T.P., Bussone, W.R., Duma, S.M. (2006). "The Effect of Gender and Body Size on Linear Accelerations of the Head Observed During Daily Activities" Biomedical Sciences Instrumentation 42: 25-30.

51 Vijayakumar, V., Scher, I., Gloeckner, D.C., et al. (2006). Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living (SAE 2006-01-0247). Warrendale, PA. Society of Automotive Engineers.

52 Choi, H., and Vanderby, R. (2000). "Muscle Forces and Spinal Loads at C4/5 Level During Isometric Voluntary Efforts." Medicine & Science in Sports & Exercise 830-838.

53 Moroney, S.P., Schultz, A.B., and Miller, J.A.A. (1988). "Analysis and Measurement of Neck Loads." Journal of Orthopaedic Research 6: 713-720.

54 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

seat belt would have primarily engaged Mr. Willis's bony left clavicle and pelvis distributing the load over his entire torso and limiting his motion. Therefore, Mr. Willis's thoracic and lumbosacral spine motion would have been limited to only minimal lateral bending and/or flexion during the subject incident. As a result, the motion of Mr. Willis's thoracic and lumbosacral spine during the subject incident would have been limited to within normal physiologic limits.

Researchers have frequently exposed human volunteers to both frontal and lateral impact accelerations at levels comparable to and greater than that of the subject incident.[55,56,57,58,59,60,61,62] No thoracic or lumbar biomechanical failures were reported and kinematics documented. Additionally, occupant kinematics were inconsistent with the biomechanical failure mechanism responsible for the thoracic and lumbar failures. Published guidelines for safe human exposure to frontal and lateral impacts are consistent with the results from these studies.[63] These data provide support for the conclusions described previously regarding Mr. Willis's response to the subject incident. In addition, these data demonstrate that the forces and accelerations of the subject incident were maintained within human tolerance.

Previous research has shown that thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[64] In addition, previous peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[65] Studies by Rohlmann et al.[66,67,68] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the lumbar spine. Finally, the forces created by the incident

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55 Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

56 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

57 Kumar, S., Ferrari, R., Narayan, Y., (2005). "Kinematic and Electromyographic Response to Whiplash-Type Impacts. Effects of Head Rotation and Trunk Flexion." Clinical Biomechanics 20: 553-568.

58 Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

59 Zaborowski, A.B. (1964). Human Tolerance to Lateral Impact (SAE 640843). Warrendale, PA, Society of Automotive Engineers.

60 Zaborowski, A.B. (1964). Lateral Impact Studies (SAE 650955). Warrendale, PA, Society of Automotive Engineers.

61 Ewing, C., Thomas, D., et al., (1977). Dynamic Response of the Human Head and Neck to +Gy Impact Acceleration (SAE 770928). Warrendale, PA, Society of Automotive Engineers.

62 Ewing, C., Thomas, D., et al., (1978). Effect of Initial Position on the Human Head and Neck Response to +Y Impact Acceleration (SAE 780888). Warrendale, PA, Society of Automotive Engineers.

63 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

64 Ng, T.P., Bussone, W.R., Duma, S.M., (2006) Thoracic and Lumbar Spine Accelerations in Everyday Activities. *Biomedical Sciences Instrumentation*, 42:410-415.

65 Kavcic, N., Grenier, S., McGill, S., (2004) Quantifying Tissue Loads and Spine Stability While Performing Commonly Prescribed Low Back Stabilization Exercises. *Spine*, 29(20):2319-2329.

66 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

67 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

68 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

were well within the limits of human tolerance for the lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Mr. Willis, a causal link between the subject incident and claimed lumbar biomechanical failures cannot be made.

Left Shoulder

According to the medical records and available documents, Mr. Willis attributes left shoulder sprain/strain to the subject incident. As stated previously, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur.

The group of muscles that surround the shoulder joint are collectively known as the rotator cuff. The supraspinatus, infraspinatus, subscapularis, and teres minor are the four muscles of the "rotator cuff." A rotator cuff sprain, or shoulder soft tissue failure, refers to inflammation of the rotator cuff tendons and the bursa that surrounds these tendons. The two mechanisms cited in the literature to cause these shoulder biomechanical failures are indirect loading of the shoulder while the arm is abducted and repetitive microtrauma to the abducted shoulder joint.[69] Repetitive microtrauma of the shoulder, the latter mechanism, is a consequence of overuse and not due to an acute traumatic event. The former mechanism, indirect loading of the shoulder, requires that the arm (not the forearm) be abducted above the shoulder and that any forces be applied through the arm into the shoulder. The rotator cuff muscles are commonly failed during repetitive use of the upper limb above the horizontal plane, e.g., during throwing, racket sports, and swimming.[70]

Mr. Willis's torso would have moved primarily rightward relative to the subject vehicle's interior, and would have been limited by the seat belt which would have engaged Mr. Willis's bony left clavicle and pelvis. The restraint provided by the seat belt restraint and seatback were such that any motion of Mr. Willis's shoulders would have been limited to well within the range of normal physiological limits.

Common activities would directly load Mr. Willis's shoulders multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident.[71,72,73,74] These data demonstrate that the shoulder forces and accelerations of the subject incident did not exceed Mr. Willis's personal tolerance.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash

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69 Moore, K.L. and Dalley, A.F. (1999) Clinically Oriented Anatomy, Fourth Edition, Lippincott Williams and Wilkins

70 Braun, S., Kokmeyer, D., and Millett, P.J., et al., (2009). *Shoulder Injuries in the Throwing Athlete.* Journal of Bone and Joint Surgery 91: 966-978.

71 Ni Westerhoff, P., Graichen, F., Bender, A., et al., (2009) "In Vivo Measurement of Shoulder Joint Loads During Activities of Daily Living." Journal of Biomechanics, In Press.

72 Murray, I.A., and Johnson, G.R. (2004). "A Study of the External Forces and Moments at the Shoulder and Elbow While Performing Everyday Tasks." Clinical Biomechanics. 19: 586-594.

73 Anglin, C., Wyss, U.P., and Pichora, D.R. (1997). "Glenohumeral Contact Forces During Five Activities of Daily Living." Proceedings of the First Conference of the ISG.

74 Bergmann, G., Graichen, F., Bender, A., et al., (2007). "In Vivo Glenohumeral Contact Forces – Measurements in the First Patient 7 Months Postoperatively." Journal of Biomechanics. 40: 2139-2149.

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event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported left shoulder biomechanical failures of Mr. Willis cannot be made.

Personal Tolerance Values

The available records indicated that Mr. Willis was capable of performing normal activities of daily living. Daily activities can produce greater movement, or stretch, to the soft tissues of Mr. Willis and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed.

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Mr. Willis's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Mr. Willis using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On February 13, 2015, Mr. Eric Willis was the seat-belted driver of a 2015 Toyota Tacoma travelling through an intersection in Redmond, Washington, when contact occurred between the rear of the subject Toyota and the front of a 2011 Ford Fusion at a low speed.
2. The severity of the subject incident was consistent with a Delta-V less than 10 miles per hour with an average acceleration less than 3.0g for the subject 2015 Toyota Tacoma in which Mr. Willis was seated.
3. The acceleration experienced by Mr. Willis was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. Had the forces of the subject incident been sufficient to overcome the muscle reaction forces, Mr. Willis's body would have moved rightward relative to the vehicle's interior. These motions would have been limited and well controlled by the three-point restraint and seat friction. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Willis's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Willis's claimed lumbar biomechanical failures. As such, a causal relationship between the subject incident and the lumbar biomechanical failures cannot be made.
7. There is no biomechanical failure mechanism present in the subject incident to account for Mr. Willis's claimed left shoulder biomechanical failures. As such, a causal relationship between the subject incident and the left shoulder biomechanical failures cannot be made.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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June 22, 2018

Milana Hutchinson, Esquire
Law Offices of Mark Dietzler
1191 2nd Avenue
Suite 500
Seattle, WA 98101

Re: *Hwang, Seon Kyu v. Tracy Lord*
File No.: 8959 3095 6036
ARCCA Case No.: 2107-1555

Dear Ms. Hutchinson:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Seon Hwang. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on June 1, 2017, Mr. Seon Hwang was the seat-belted driver of a 2007 Honda Civic traveling on SR 99 near Lynnwood, Washington. Ms. Morgan Lord was the driver of a 2004 Chevrolet Tahoe traveling immediately behind the subject Honda Civic. While the subject Honda was stopped, contact was made between the rear of the subject Honda and the front of the incident Chevrolet. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, *Report No. E677881*
- Seventy-one (71) color photographic reproductions of the subject 2007 Honda Civic
- Five (5) color photographic reproductions of the incident 2004 Chevrolet Tahoe
- Preliminary Estimate for repairs to the subject 2007 Honda Civic [June 12, 2017]
- Estimate of Record for the subject 2007 Honda Civic [June 14, 2017]
- Preliminary Supplement 1 with Summary for the subject 2007 Honda Civic [June 20, 2017]
- Supplement of Record 1 Summary for the subject 2007 Honda Civic [June 22, 2017]
- Complaint, *Seon Kyu Hwang vs. Morgan Lord* [April 12, 2018]
- VinLink data sheet for the subject 2007 Honda Civic
- Expert AutoStats data sheets for a 2007 Honda Civic
- VinLink data sheet for the incident 2004 Chevrolet Tahoe
- Expert AutoStats data sheets for a 2004 Chevrolet Tahoe
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair documents of the subject 2007 Honda Civic, and photographic reproductions of the incident 2004 Chevrolet Tahoe in association with accepted scientific methodologies.[6,7]

The repair documents for the subject Honda Civic reported damage to the rear bumper cover, energy absorber, impact bar, right impact bar bracket, and rear body panel. Prior damage was noted to the trunk lid. The photographs depicted scrapes to the rear bumper cover, along with a tear on the top face (Figure 1). There was a dent at the top of the rear face on the trunk lid that was noted as pre-existing to the subject incident. There was also a crack in the foam absorber near the center.

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[6] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[7] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 2007 Honda Civic

The photographs of the 2004 Chevrolet Tahoe depicted a dent to the front bumper face near the left of the license plate (Figure 2). There was no crush to the grille, headlamps, or hood.

Figure 2: Reproductions of photographs of the incident 2004 Chevrolet Tahoe

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Honda Civic, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[8] The IIHS tested an exemplar 2007 Honda Civic in a 6.2 miles per hour (mph) rear impact into a full-width barrier.[9] The test Honda sustained damage to the rear body panel, rear bumper reinforcement, rear bumper cover, left/right bumper mounting brackets, and energy absorber. The primary damage to the subject Honda Civic was to the rear bumper cover, energy absorber, impact bar, and rear body panel. Thus, because the test Honda Civic in the IIHS rear impact test sustained comparable damage, the severity and energy transfer of the IIHS impact is comparable to the severity of the subject incident. Accounting for restitution, the subject Honda experienced a Delta-V of 8.0 mph.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with an 8.0 mph Delta-V is 2.4g.[10,11,12,13] By the laws of physics, the average acceleration experienced by the subject Honda Civic in which Mr. Hwang was

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8 Siegmund, G.P., et al., (1996) Us*ing Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

9 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2008 Honda Civic, September 2008.

10 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

11 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

12 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

13 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

seated was 2.4g. This is consistent with an energy crush analysis to the rear of an exemplar 2007 Honda Civic.[14,15,16,17]

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that a person experiences 1g of loading while in a sedentary state. Therefore, Mr. Hwang experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[18] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

The available records indicate Mr. Hwang was 72" in height, weighed approximately 256 pounds, and was 29 years old at the time of the subject incident. The laws of physics dictate that when the subject Honda Civic was contacted in the rear, it would have been pushed forward causing Mr. Hwang's seat to move forward relative to his body. This motion would result in Mr. Hwang moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Mr. Hwang's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Mr. Hwang was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Mr. Hwang's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Mr. Hwang would have been limited to well within the range of normal physiological limits.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[19,20,21,22] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[23] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were

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14 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

15 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

16 EDCRASH, Engineering Dynamics Corp.

17 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

18 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

19 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

20 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

21 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

22 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

23 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[24,25]

Studies by Rohlmann et al.[26,27,28] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[29] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[30]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On June 1, 2017, Mr. Seon Hwang was the seat-belted driver of a 2007 Honda Civic stopped in SR 99 near Lynnwood, Washington, when contact occurred between the rear of the Honda and the front of a 2004 Chevrolet Tahoe at a low speed.
2. The severity of the rear impact during the subject incident was 8.0 miles per hour with an average acceleration of 2.4g.
3. Had there been enough energy transferred to cause any motion, the Honda Civic would have been accelerated and pushed forward, coupling an occupant's motion to the vehicle, and causing the body to load into the seat and seatback.

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24 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

25 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

26 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

27 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

28 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

29 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

30 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

4. The energy imparted to Mr. Hwang in the subject Honda Civic was well within the limits of human tolerance. Without exceeding these limits, or the normal range of motion, one would not expect a biomechanical failure mechanism in the subject incident.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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July 9, 2018

Riley Lovejoy, Esquire
Law Offices of Sweeney & Dietzler
1001 4th Avenue
Suite 3300
Seattle, WA 98154

Re: *Smith, Pamela v. Terry Dievendorf, Gabrielle Calhoun and Gary Vowels*
Claim No.: 6329 8297 5002
ARCCA Case No.: 2107-1490

Dear Mr. Lovejoy:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Pamela Smith. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on December 5, 2014, Ms. Pamela Smith was the driver of a 2013 Mercedes Benz C300 travelling southbound on I-405 in Kirkland, Washington. A Ford Focus driven by Gabriele Calhoun was travelling in the lane to the right of the subject Mercedes. As the incident Ford changed lanes to the left and slowed to a stop, contact was made between the front of the subject Mercedes and the rear of the incident Ford. No airbags were deployed, and both vehicles were driven from the scene.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Complaint, *Pamela Smith v. Terry Dievendorf* [August 3, 2017]
- Twenty-four (24) color photographic reproductions of the subject 2013 Mercedes Benz C300
- Twenty-nine (29) color photographic reproductions of the incident Ford Focus
- Final Bill for the subject 2013 Mercedes Benz C300 [December 12, 2014]
- Deposition transcript from Pamela Smith [April 9, 2018]
- Deposition transcript from Terry Dievendorf [May 21, 2018]
- Deposition transcript from Gabriele Calhoun [June 25, 2018]
- VinLink data sheet for the subject 2013 Mercedes Benz C300
- Expert AutoStats data sheets for a 2013 Mercedes Benz C300
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2013 Mercedes Benz C300 and photographic reproductions of the incident Ford Focus in association with accepted scientific methodologies. [6,7]

The repair documentation for the subject Mercedes reported the damage to the front bumper cover. The photographs depicted no residual crush to the front bumper structures (Figure 1).

[6] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[7] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

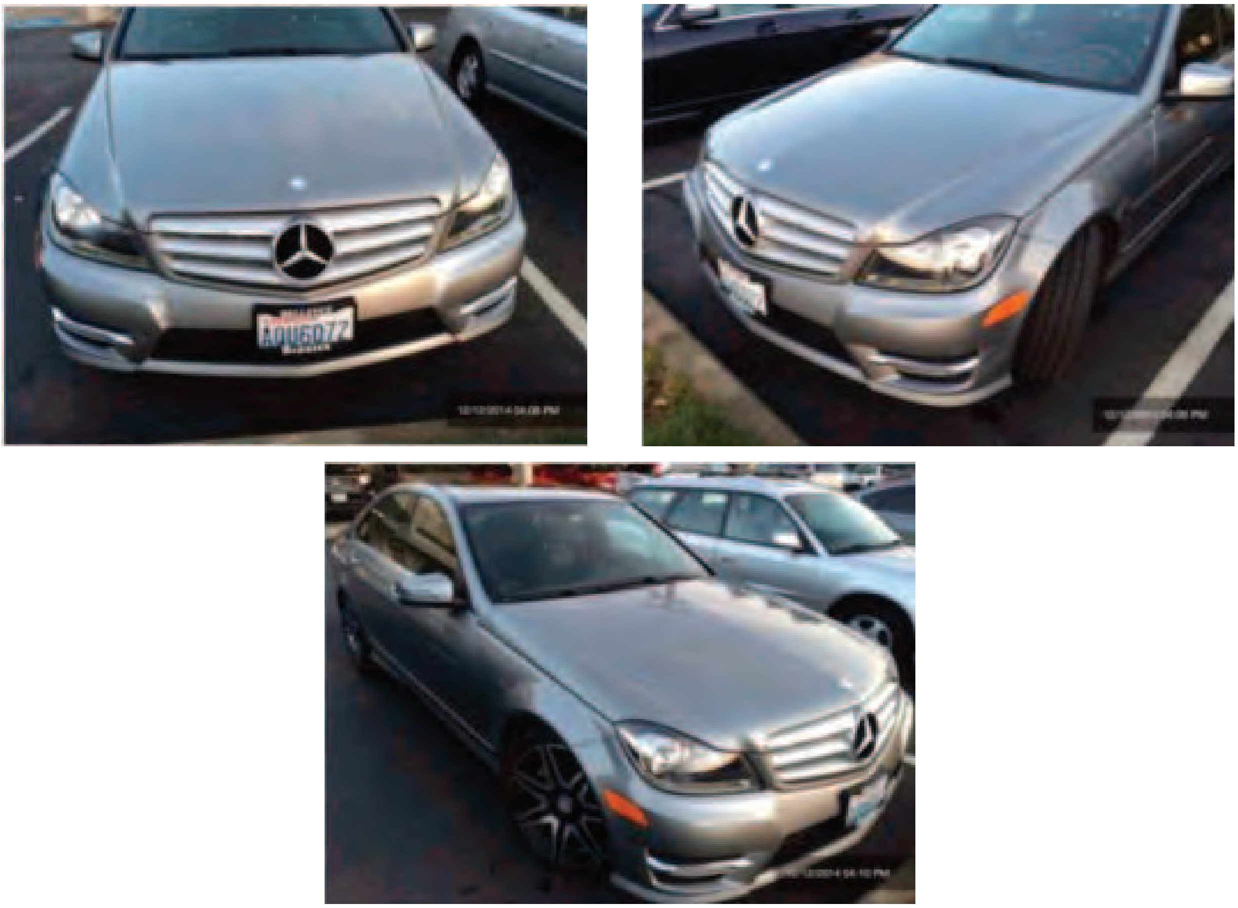

Figure 1: Photographic reproductions of the subject 2013 Mercedes Benz C300

The photographs of the incident Ford Focus depicted no damage to the rear bumper structures (Figure 2).

Figure 2: Photographic reproductions of the incident Ford Focus

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[8,9,10,11,12] Analyses of the photographs and geometric measurements, along with the repair record of the subject 2013 Mercedes Benz revealed the damage due to the subject incident. An energy crush analysis[13,14] indicates that a single 10 miles per hour (mph) flat barrier impact to the rear of an exemplar Mercedes would result in significant and visibly noticeable crush across the entirety of the subject Mercedes's frontal structure, with a residual crush of 2.5 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mph Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[15] The lack of significant structural crush to the entire front of the subject Mercedes Benz indicates a collision resulting in a Delta-V significantly below 10 mph.

The IIHS tested several cars of the same era from the same manufacturer as the subject 2013 Mercedes Benz, as well as vehicles from other manufacturers. In a 6.2 mph frontal impact into a flat barrier, the test vehicles sustained comparable if not more significant damage to the front bumper covers, hood, grill, front fender, among other parts in some tests. A test C-class Mercedes is shown in Figure 3.Thus, because the test vehicles in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is comparable, if not greater than, the severity of the subject incident, and places the subject incident speed more comparable to the test speed of 6.2 mph.

Figure 3. Test Mercedes C-class after 6.2 mile-per-hour impact

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8 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

9 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

10 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

11 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

12 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

13 EDCRASH, Engineering Dynamics Corp.

14 PC-Crash Collision Software.

15 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mph impact is 3.0g and 1.9g for a 6.2 mph impact.[16,17,18,19] By the laws of physics, the average acceleration experienced during the frontal impact by the subject Mercedes Benz in which Ms. Smith was seated was significantly less than 3.0g and consistent with 1.9g.

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that a person experiences 1g of loading while in a sedentary state. Therefore, Ms. Smith experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[20] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Upon impact between the rear of the Focus and the front of the subject Mercedes, the laws of physics dictate the Mercedes would have been decelerated longitudinally. Had the forces generated during this interaction been sufficient to overcome the muscle reaction forces, a human body would have moved primarily forward relative to the Mercedes's interior. The three-point restraint would have locked when the vehicle accelerations exceeded 0.7g.[21] The seat belt would support and limit forward body excursion. Friction generated at the seat bottom, as well as the passive muscle resistance of the arms would have acted in conjunction with the three-point restraint to limit body motion. The low accelerations in the subject incident and the restraint provided by the seatback and seat belt system, then, were such that any motion of an occupant would have been limited to well within the range of normal physiological limits.

Several researchers have assessed the human body's response to frontal impact accelerations. Nielsen et al.[22] conducted a series of aligned front-to-rear motor vehicle collisions with human volunteers positioned in each vehicle. The Delta-V of the bullet (striking) vehicle was comparable to or greater than that associated with the subject vehicle, and no chronic thoracic or lumbar biomechanical failures were reported. Siegmund and Williamson[23] investigated frontal impacts using amusement park bumper cars and belted human volunteers. The Delta-V of the striking vehicle in this series of tests was comparable to that associated with the subject incident, and none of the participants reported any

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16 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

17 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

18 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

19 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

20 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

21 Code of Federal Regulations, Federal Motor Vehicle Safety Standard. Title 49, Part 571, Section 209.

22 Nielsen, G.P., Gough, J.P., et al. (1997). Human Subject Responses to Repeated Low Speed Impacts using Utility Vehicles (SAE 970394). Warrendale, PA, Society of Automotive Engineers.

23 Siegmund, G., and Williamson, P. (1993). "Speed Change (ΔV) of Amusement Park Bumper Cars." Canadian Multidisciplinary Moor Vehicle Safety Conference VIII.

chronic thoracic or lumbar biomechanical failures. Research by Chandler and Christian subjected three-point and two-point restrained human volunteers to frontal impacts with an acceleration level of 12g.[24] None of the participants reported any chronic thoracic or lumbar spine biomechanical failures. Arbogast et al.[25] subjected human volunteers to 3g frontal impacts without any reported onset of pain, stiffness, or biomechanical failure to any participants. Research by Weiss et al.[26] demonstrated that human subjects have regularly and repeatedly been subjected to frontal impact acceleration levels up to 15g without any permanent physiological changes or chronic biomechanical failures.

Studies by Rohlmann et al.[27,28,29] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[30] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[31]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On December 5, 2014, Ms. Pamela Smith was the seat-belted driver of a 2013 Mercedes Benz C300 travelling southbound on I-405 in Kirkland, Washington, when contact with the Ford Focus occurred to the front of the subject Mercedes at a low speed.

2. The severity of the frontal impact during the subject incident was significantly below 10 miles per hour with an average acceleration less than 3.0g and consistent with 1.9g.

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[24] Chandler, R.F., and Christian, R.A., (1970). Crash Testing of Humans in Automobile Seats (SAE 700361). Warrendale, PA, Society of Automotive Engineers.

[25] Arbogast, K.B., Balasubramanian, S., Seacrist, T., et al., (2009). Comparison of Kinematic Response of the Head and Spine for Children and Adults in Low-Speed Frontal Sled Tests (SAE 2009-22-0012). Warrendale, PA, Society of Automotive Engineers.

[26] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[27] Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

[28] Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

[29] Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

[30] Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

[31] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

3. The acceleration experienced by Ms. Smith was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subsequent frontal impact would tend to move the occupant's body forward relative to the vehicle's interior. These motions would have been limited and well controlled by the seat structures and three point restraint system. All motions would be well within normal movement limits.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

ARCCA INCORPORATED

BRADLEY W. PROBST, M.S.B.M.E.

PROFESSIONAL BIOGRAPHICAL OUTLINE

BACKGROUND

Mr. Probst earned a B.S. in Mechanical Engineering at University of Louisiana, Lafayette, Louisiana, and an M.S. in Biomedical Engineering at Tulane University, New Orleans, Louisiana. For his Ph.D. research at Tulane, Mr. Probst developed the most advanced kinematic model of the human cervical spine known to date. This unique model will be used to make technological advances to Naval pilot ejection and recovery systems. In addition, Mr. Probst has also done advanced course work in the fields of biomaterials, materials engineering, biosolid mechanics, mechanisms of bodily functions, and advanced finite element analysis. He has also lectured extensively and shared teaching responsibilities for courses in biomedical engineering and design and analysis at Tulane University.

As a biomedical consultant for a national accident investigation firm and while a student, Brad gained valuable experience in forensic analysis while working on a university project to research soft tissue injury caused by dynamic inertial loading.

While investigating and presenting work on bone morphology, his focus was the proper use of computation modeling as it related to bone material property identification. His significant contributions led to important developments in the field of bone mechanics and response of living bone to stress and disease.

SUMMARY OF EXPERIENCE

- Developed his skills in mechanical engineering while acting as project engineer at a petrochemical facility, where he was responsible for several multimillion-dollar expansion and renovation projects
- Pursued graduate research on a federally funded project to investigate spinal trauma and human head and neck tolerances to dynamic impact loadings
- Performed finite element analysis, computer modeling, material testing and data analysis
- Used advanced numerical methods for model validation
- Operated state-of-the-art high-speed computers to develop his calibrated model and to validate biofidelity
- Created an accurate biofidelic model of the kinematic response of the human head and neck during any general 3D acceleration through the development of a finite element model. The conclusions and results of this important project will be used to make technological advances toward improving the safety of pilots during ejection and major recovery system improvements
- Uses his biomedical and mechanical engineering skills to analyze the relationship of crash injuries to crash forces, occupant kinematics, and human tolerance
- Uses forensic investigation and accident reconstruction techniques to develop injury mitigation devices

AREAS OF SPECIALTY

- Biomechanical Consulting
- Human Injury Tolerance
- Vehicular Accident Reconstruction
- Impact and Inertial Trauma Analysis
- Injury Mechanism and Mitigation Analysis
- Slip and Fall Analysis

ACADEMIC BACKGROUND

- Tulane University, New Orleans, LA, Ph.D. Candidate, Biomedical Engineering
- Tulane University, New Orleans, LA, M.S., Biomedical Engineering, 1996
- University of Louisiana, Lafayette, LA, B.S., Mechanical Engineering, 1988

PROFESSIONAL EXPERIENCE

January 2000 – Present | ARCCA, Incorporated | Senior Biomechanist

- Specializes in injury analysis, injury mechanism determination and crash kinematics
- Practices biomechanics to explore the cause, nature and severity of injuries
- Utilizes medical records, testing, computer modeling and his extensive knowledge of human injury tolerance to determine whether a claimed injury is consistent with a specific set of actions or exposure to a specific accident environment

1995 – 2000 | Tulane University | Research Assistant

- Pursued graduate research on a spinal trauma investigation and analysis project funded by the Office of Naval Research. His position was secured, fully funded and compensated through competitive selection
- Performed finite element analysis, computer modeling, material testing, and data analysis to develop biofidelic human cervical spine analog
- Utilized advanced numerical methods for model validation
- Proposed conclusions and research results that will be used to implement technological advancements in naval pilot ejection and recovery systems

1997 – 1999 | Unified Investigations & Sciences, Inc. | Biomechanical Consultant

- Performed forensic analysis of soft tissue injury from mild impact in automotive accidents
- Determined impact levels through vehicular accident reconstruction, and compared findings to determine injury causation and severity
- Presented written conclusions to clients and provided expert testimony relative to his findings

May 1995 – 1999 | Tulane University | Teaching Assistant

- Selected by faculty mentor to assist with and share teaching responsibilities for courses such as Statics, Introduction to Biomedical Engineering and Design and Analysis
- Collaborated with mentor to plan lectures
- Prepared of course material
- Presented lectures

1988 – 1995 | Wink Engineering | Mechanical/Project Engineer

- Managed and was responsible for several multimillion-dollar expansion and renovation projects at a petrochemical facility
- Directed and performed environmental remediation (air and water)
- Recommended and implemented improvements to waste water treatment systems

PROFESSIONAL AFFILIATIONS

- Association for the Advancement of Automotive Medicine
- Society of Automotive Engineers (SAE)
- American Society of Safety Engineers (ASSE)
- American Society of Mechanical Engineers (ASME)

PUBLICATIONS

Probst, B, R. Anderson, G. Harris, R. Hart. (2007). *A Three-Dimensional Nonlinear Kinematic Finite Element Model of the Human Cervical Spine Under Dynamic Inertial Loading.* American Society of Biomechanics Biomechanics Symposium 2007, Stanford University: ASB.

Cantor, A., M. Markushewski, L. D'Aulerio, B. Benda, D. Eisentraut, **B. Probst**, L. Sicher. (2007). *Seat Design: A Risk Benefit Approach*. ASSE.

Probst, B. (Presenter). (2007). *Industrial vs. Academic Perspectives on Bioengineering Education*. ASME Summer Bioengineering Conference. Keystone, CO: ASME.

Probst, B., R. Anderson, T. Hart, G. Harris, S. Guccione. (2007). *A Three-Dimensional Nonlinear Kinematic Finite Element Model of the Human Cervical Spine Under Dynamic Inertial Loading.* American Society of Biomechanics Northwest Biomechanics Symposium 2007, Eugene, Oregon: ASB.

Markushewski, M., Gushue, D., **Probst, B.**, Coward, C., (2007). *When Driver Safety Fails—Then What? Vehicular Accident Analysis: The Big Picture*. ASSE.

Gushue, D.L., Joganich, T., **Probst. B. W.**, Markushewski, M. (2007). *Biomechanics for Risk Managers—Analysis of Slip, Trip & Fall Injuries*. ASSE.

Gushue, D., **B. Probst**, et al. (2006). *Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts*. Safety 2006, Seattle, WA, ASSE.

Benda, B. J., L. D'Aulerio, A. Cantor, M. L. Markushewski, **B. Probst**, et al. (2006). *Performance of Automotive Seat Belts During Inverted (-Gz) Rollover Drop Tests*. Icrash 2006—International Crashworthiness Conference, Athens, Greece, University of Bolton.

Coleman, J.C., **Probst, B.W.**, Roberts, M.D., and Hart, R.T. (1999). *Meshes Based On Cube-Shaped Finite Elements Do Not Converge: Quadratic Tetrahedral Elements Are An Alternative. Proceedings of the 1999 Summer Bioengineering Conference (ASME)* Big Sky, MT, June 1999. (pp. 329-230) New York: ASME.

Coleman, J.C., **Probst, B.W.**, Roberts, M.D., and Hart, R.T. (1998). *Investigating the Convergence Behavior of Voxel-Based Finite Element Meshes*. *Proceedings of the 7th Annual Symposium on Computational Methods in Orthopaedic Biomechanics*, Anaheim, CA, February 1998. Chicago: Orthopaedic Research Society (ORS).

COURSE INSTRUCTION

- *Slip/Trip/Falls*, Rocky Mountain IASIU Chapter, Denver, CO. May 7, 2009
- *Biomechanics*, Puget Sound Special Investigators, Seattle, WA. July 30, 2009
- *Slip/Trip/Falls*, Las Vegas IASIU Chapter, Las Vegas, NV. December 7, 2009
- *Low Speed Impacts*, Oregon IASIU Chapter, Portland, OR. May 4, 2010
- *Slip/Trip/Falls*, Oregon IASIU Chapter, Portland, OR. Oct 7, 2011
- *Biomechanics*, Hawaii RIMS Chapter, Honolulu, HI. September 15, 2011
- *Determining Injury Causation*, Alaska RIMS Chapter, Anchorage, AK. October 19, 2011
- *Biomechanics*, OR RIMS Chapter, Portland, OR. June 20, 2013
- *Determining Injury Causation*, Los Angeles RIMS Chapter, September 17, 2014

OTHER PROFESSIONAL ACTIVITIES

Judge at the Edmonds Annual Hot Autumn Nites Car Show, Edmonds, WA,
September 6, 2008 sponsored by the Greater Edmonds Chamber of Commerce

ARCCA, INCORPORATED
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August 14, 2018

Riley Lovejoy, Esquire
Law Offices of Sweeney & Dietzler
1001 4th Avenue
Suite 3300
Seattle, WA 98154

Re: *Smith, Pamela v. Terry Dievendorf, Gabrielle Calhoun and Gary Vowels*
Claim No.: 6329 8297 5002
ARCCA Case No.: 2107-1490

Dear Mr. Lovejoy:

Thank you for the opportunity to participate in the above-referenced matter. ARCCA, Incorporated was retained to evaluate the subject incident in relation to the forces involved in the incident of Pamela Smith. This letter is meant to supplement my report of July 9, 2018 regarding Pamela Smith.

Conclusions:

In addition to my opinions from my report dated July 9, 2018, these conclusions are meant to further supplement and have not changed the opinion of my previous analysis.

Ms. Calhoun reported that that traffic was coming to a stop up ahead. Ms. Smith also testified that she had begun slowing for traffic. This confirms that Ms. Smith should have been prepared to slow or stop in anticipation of the traffic up ahead when the incident Ford changed lanes in front of her. Additionally, Ms. Calhoun overreacted by changing lanes to the left due to anticipated movement of the incident Honda Element.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

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July 12, 2018

Joseph Kopta, Esquire
Kopta & Macpherson
5801 Soundview Drive
Suite 258
Gig Harbor, WA 98335

Re: *Chalal, Amelie v. Craig Malke*
ARCCA Case No.: 3691-032

Dear Mr. Kopta:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Amelie Chalal. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

ARCCA INCORPORATED

Incident Description:

According to the available documents, on August 19, 2014, Mr. Amelie Chalal was the seat-belted driver of a 2011 Toyota RAV4 traveling on 100th Avenue NE in Bothell, Washington. Mr. Craig Malke was the driver of a 1997 Ford Expedition traveling immediately behind the subject Toyota. While stopped for traffic, contact was made between the rear of the subject Toyota and the front of the incident Ford.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- State of Washington Police Traffic Collision Report, Report No. 3426497 [August 19, 2014]
- Twenty-six (26) color photographic reproductions of the subject 2011 Toyota RAV4
- Sixteen (16) color photographic reproductions of the incident 1997 Ford Expedition
- Estimate of Record for the subject 2011 Toyota RAV4 [August 25, 2014]
- Estimate of Record for the subject 1997 Ford Expedition [August 20, 2014]
- Deposition transcript from Amelie Chalal [May 16, 2018]
- Deposition transcript from Craig Malke [October 25, 2017]
- Medical Records pertaining to Amelie Chalal
- VinLink data sheet for the subject 2011 Toyota RAV4
- Expert AutoStats data sheets for a 2011 Toyota RAV4
- VinLink data sheet for the incident 1997 Ford Expedition
- Expert AutoStats data sheets for a 1997 Ford Expedition
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

1. Identify the biomechanical failures that Ms. Chalal claims were caused by the subject incident on August 19, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 2011 Toyota RAV4;

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

3. Determine Ms. Chalal's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Chalal's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Chalal attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
  - Sprain/strain
- Right Wrist/Hand
  - Sprain/strain
  - Tendonitis
  - Synovitis/Tenosynovitis

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 2011 Toyota RAV4 and the incident 1997 Ford Expedition in association with accepted scientific methodologies.[11,12]

The repair estimate for the subject 2011 Toyota RAV4 reported damage to the rear bumper cover, scuff plate with spare tire, reinforcement beam, left/right side support, left/right lens and housing, spare carrier, spare cover, door shell, weatherstrip, left/right trim cover upper black left/right trim cover lower black, emblem, nameplate 'RAV4', door glass, wiper motor, glass trim upper, left/right glass trim side, lower door trim, rear body inner panel, rear body outer panel, rear floor panel, trim panel base, right quarter panel, left quarter panel, left/right protect strip, and right strip. Additionally, it was reported that a set up and measure and a pull mash was required. The photographs of the subject Toyota depicted significant crush to the rear bumper structures, spare tire, and rear body, as well as a broken rear glass window (Figure 1).

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 2011 Toyota RAV4

The repair documents for the incident 1997 Ford Expedition indicated there was damage to the front bumper chrome, pad assembly, license bracket, left/right bumper mount plate, left/right bumper side bracket, valance, grille, hood, deflector wraparound, and left/right nameplate. The photographs depicted crush to the hood and a crack to the right side of the grille (Figure 2).

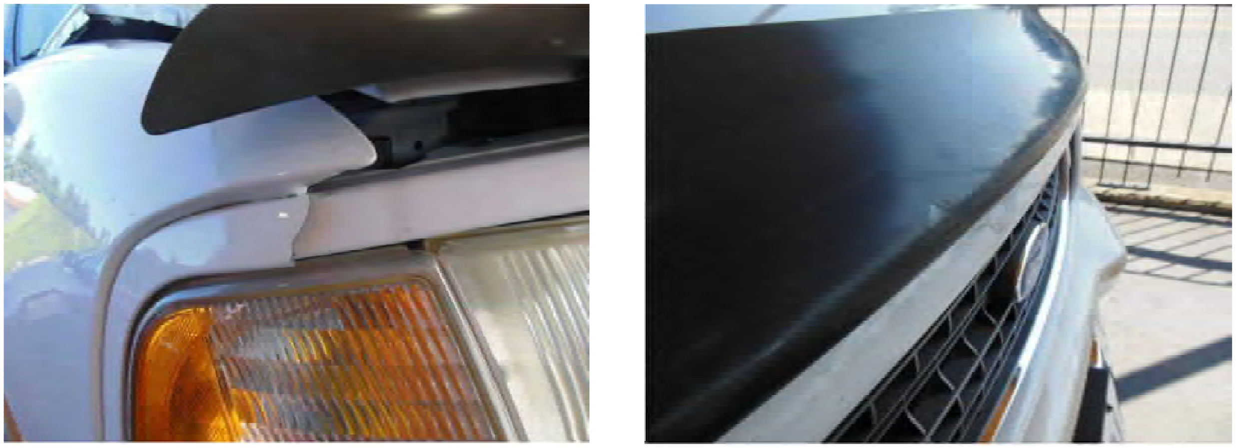

Figure 2: Reproductions of photographs of the incident 1997 Ford Expedition

Newton's Third Law of Motion states that for every action there is an equal and opposite reaction. This law dictates that a scientific analysis of the loads sustained by the incident Ford Expedition can be used to resolve the loads sustained by the subject Toyota RAV4. That is, the loads sustained by the incident Ford are equal and opposite to those of the subject Toyota. Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the incident 1997 Ford Expedition revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 miles per hour (mph) flat barrier impact to the front of an exemplar Ford Expedition would result in significant and visibly noticeable crush across the entirety of the incident Ford's front structure, with a residual crush of 4.0 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mph Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural crush to the entire front of the incident Ford indicates a collision resulting in a Delta-V significantly below 10 mph. Using the Conservation of Momentum and accounting for restitution, the subject Toyota experienced a Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) of significantly less than 15.5 mph.[20,21]

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13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.

14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.

15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.

16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.

17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.

18 EDCRASH, Engineering Dynamics Corp.

19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

20 Howard, R.P., et al., (1993) Vehicle Restitution Response in Low Velocity Collisions, (SAE 931842). Warrendale, PA, Society of Automotive Engineers.

21 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 15.5 mph Delta-V is 4.7g.[22,23,24,25] By the laws of physics, the average acceleration experienced by the subject Toyota RAV4 in which Ms. Chalal was seated was significantly less than 4.7g.

The acceleration experienced due to gravity is 1g. This means that Ms. Chalal experiences 1g of loading while in a sedentary state. Therefore, Ms. Chalal experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[26] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Chalal's medical records indicated she was 68 inches in height, weighed approximately 175 lbs., and was 31 years old at the time of the subject incident. Ms. Chalal slowed gradually to a stop for a crossing pedestrian. She testified that she saw the incident Ford approaching from behind and grabbed the steering wheel with both hands. Ms. Chalal also testified that she applied both feet to the brake. She was taken from the scene in an ambulance and developed bruising on her right hand and wrist.

The laws of physics dictate that when the subject Toyota RAV4 was contacted in the rear, it would have been pushed forward causing Ms. Chalal's seat to move forward relative to her body. This motion would result in Ms. Chalal moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Chalal's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Chalal was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Chalal's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Chalal would have been limited to well within the range of normal physiological limits[27].

Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Chalal was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there

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22 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

23 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

24 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

25 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

26 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

27 Insurance Institute for Highway Safety Rear Test SER06033: 2006 Toyota RAV4

is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[28,29]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the subject Toyota would be pushed forward and Ms. Chalal would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar Toyota RAV4 revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 31.5 inches in the full down position, and 34.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Chalal revealed she would have a normal seated height of 34.4 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Chalal's cervical spine would have undergone only a subtle degree of the characteristic response phases.[30] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[31] The cervical loads were within physiologic limits and Ms. Chalal would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[32,33,34]

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28 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

29 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

30 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

31 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

32 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

33 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

34 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to the subject incident.[35,36,37,38,39] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[40,41,42,43] The available documents reported Ms. Chalal was capable of performing regular daily activities. Additional research has shown that cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[44]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Chalal cannot be made.

Right Wrist/Hand

The medical records indicate Ms. Chalal attributes wrist sprain/strain and tendonitis, as well as hand synovitis and tenosynovitis to the subject incident. The available medical records reported a right wrist X-ray was performed on August 19, 2014 and the results were normal. Additionally, the available records reported a wrist surgery performed on July 24, 2017. A mechanism for a sprain/strain would

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[35] Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

[36] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

[37] Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

[38] Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

[39] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[40] Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

[41] Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

[42] Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

[43] Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

[44] Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

only be present if significant relative motion between Ms. Chalal's ulna/radius and bony hand structure existed during the subject incident.[45,46]

As stated previously, Ms. Chalal's torso would have moved rearward relative to the subject vehicle's interior, which would have been supported and constrained by the seatback.[47,48,49,50] During this rearward motion Ms. Chalal's arms would have been unloaded from any interior objects. Ms. Chalal testified that both hands were on the steering wheel at the time of impact. The limited motion of Ms. Chalal during the subject incident would not have caused any hyperflexion or extension. According to the available medical records, it was reported that Ms. Chalal had a hyperextension to her right wrist, which is not consistent with the subject incident. The seatback would have distributed any loading across their entire back and shoulders. Any rebound would have been limited by the seat belt which would have engaged Ms. Chalal's bony left clavicles and pelvises. The restraint provided by the seat belt restraint and seatback were such that any motion of Ms. Chalal's wrists and hands would have been limited to well within the range of normal physiological limits.

Again, activities of daily living are capable of directly loading Ms. Chalal's wrist multiple times to greater or comparable loads than the subject incident. Many studies have shown that upper extremity forces during daily living activities such as manipulating a coffee pot, turning a steering wheel, or reaching and lifting tasks are comparable to, or greater than that of the subject incident. These data demonstrate that the wrist forces and accelerations of the subject incident did not exceed Ms. Chalal's personal tolerance.

Ms. Chalal was diagnosed with tendinosis. Tendinosis is an intratendinous breakdown of collagen due to aging, microtrauma, or vascular compromise[51]. It is often seen in athletes (pitchers in baseball) and laborers (painters) who work with their arms above their heads (shoulders abducted). Overuse is commonly cited as a primary risk for tendinosis and tenosynovitis.

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the wrist. Finally, the forces created by the incident were well within the limits of human tolerance for the wrist and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Chalal, a causal link between the subject incident and claimed wrist biomechanical failures cannot be made.

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45 Whiting, W.C. and Zernicke, R.F. (1998). Biomechanics of Musculoskeletal Injury. Champaign, Human Kinetics.

46 Seiffert, U. and Wech, L. (2003). Automotive Safety Handbook. SAE International, Warrendale, PA.

47 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

48 Braun, T.A., Jhoun, J.H., Braun, M.J., et al. (2001). *Rear-end Impact Testing with Human Test Subjects*. (No. 2001-01-0168). SAE Technical Paper.

49 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

50 Ivory, M.A., Furbish, C., et al. *(2010). Brake Pedal Response and Occupant Kinematics During Low Speed Rear-End Collisions.* (No. 2010-01-0067). SAE Technical Paper.

51 Khan KM, Cook JL, Taunton JE, and Bonar F, "Overuse Tendinosis, Not Tendinitis, *The Physician and Sportsmedicine*, Vol 28, No 5, May 2000.

Personal Tolerance Values

According to the available documents, Ms. Chalal worked in shipping for Aspire Velotech, including picking and pulling bicycle orders. Ms. Chalal also testified to biking as a hobby. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Chalal and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[52]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Chalal's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Chalal using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On August 19, 2014, Ms. Amelie Chalal was the seat-belted driver of a 2011 Toyota RAV4 that was stopped on 100th Avenue in Bothell, Washington, when the subject Toyota RAV4 was contacted in the rear at low speed by a 1997 Ford Expedition.
2. The severity of the subject incident was below 15.5 miles-per-hour with an average acceleration less than 4.7g.
3. The acceleration experienced by Ms. Chalal was within the limits of human tolerance and comparable to that experienced during various daily activities.
4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Chalal's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.
5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Chalal's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.
6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Chalal's claimed right wrist biomechanical failures. As such, a causal relationship between the subject incident and the right wrist biomechanical failures cannot be made.

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52 Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

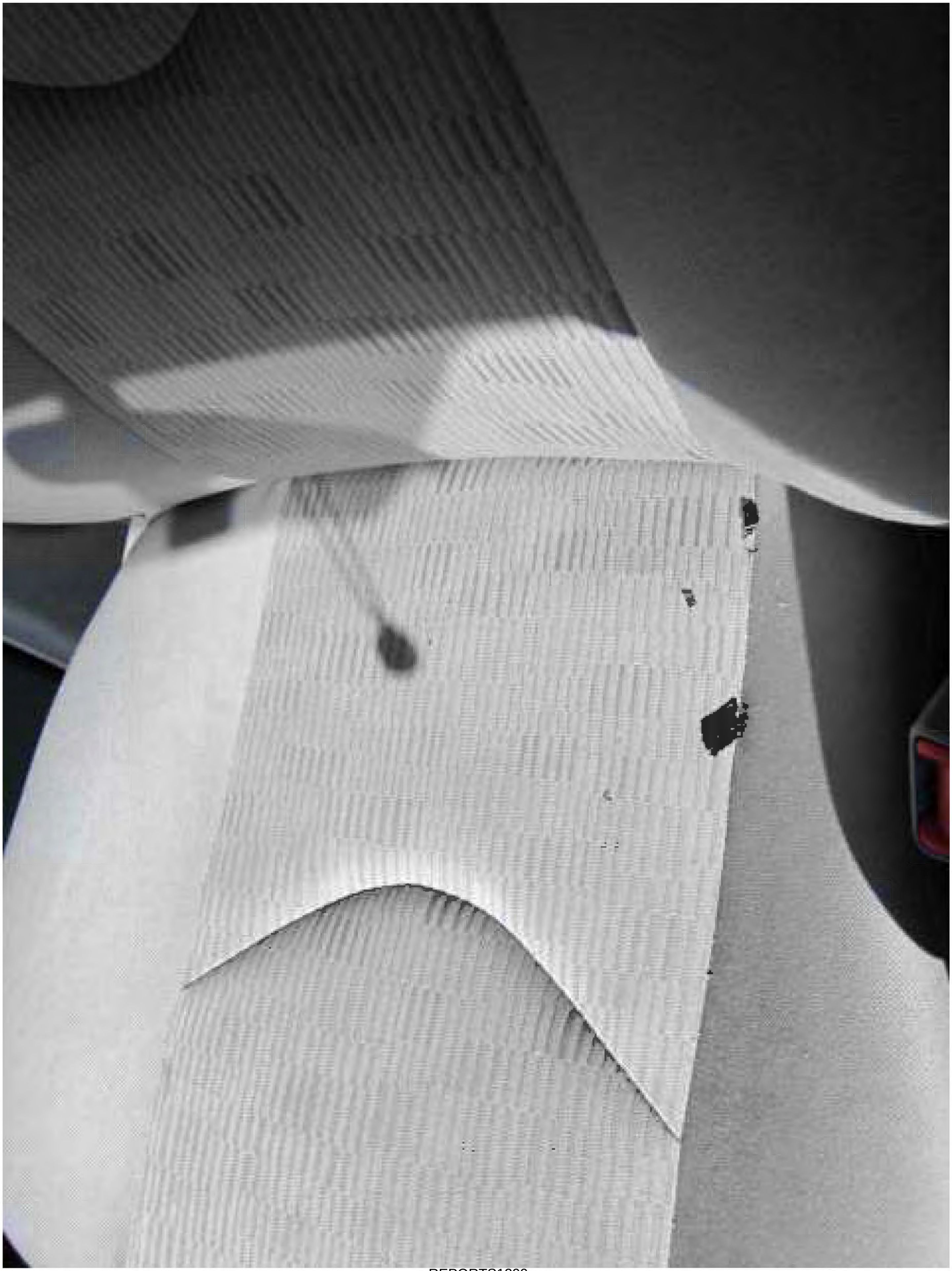
This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist


SEATTLE


19006
PROFESSIONAL
COLLISION
AUTO BODY & AUTO GLASS
PROFESSIONAL

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GVWR: 2005KG (4430LB)
GAWR: FRT. 1145KG (2535LB) WITH 225/65R17 TIRES,
17X6.5J RIMS, AT 220KPA (32PSI) COLD.
RR. 1100KG (2435LB) WITH 225/65R17 TIRES,
17X6.5J RIMS, AT 220KPA (32PSI) COLD.
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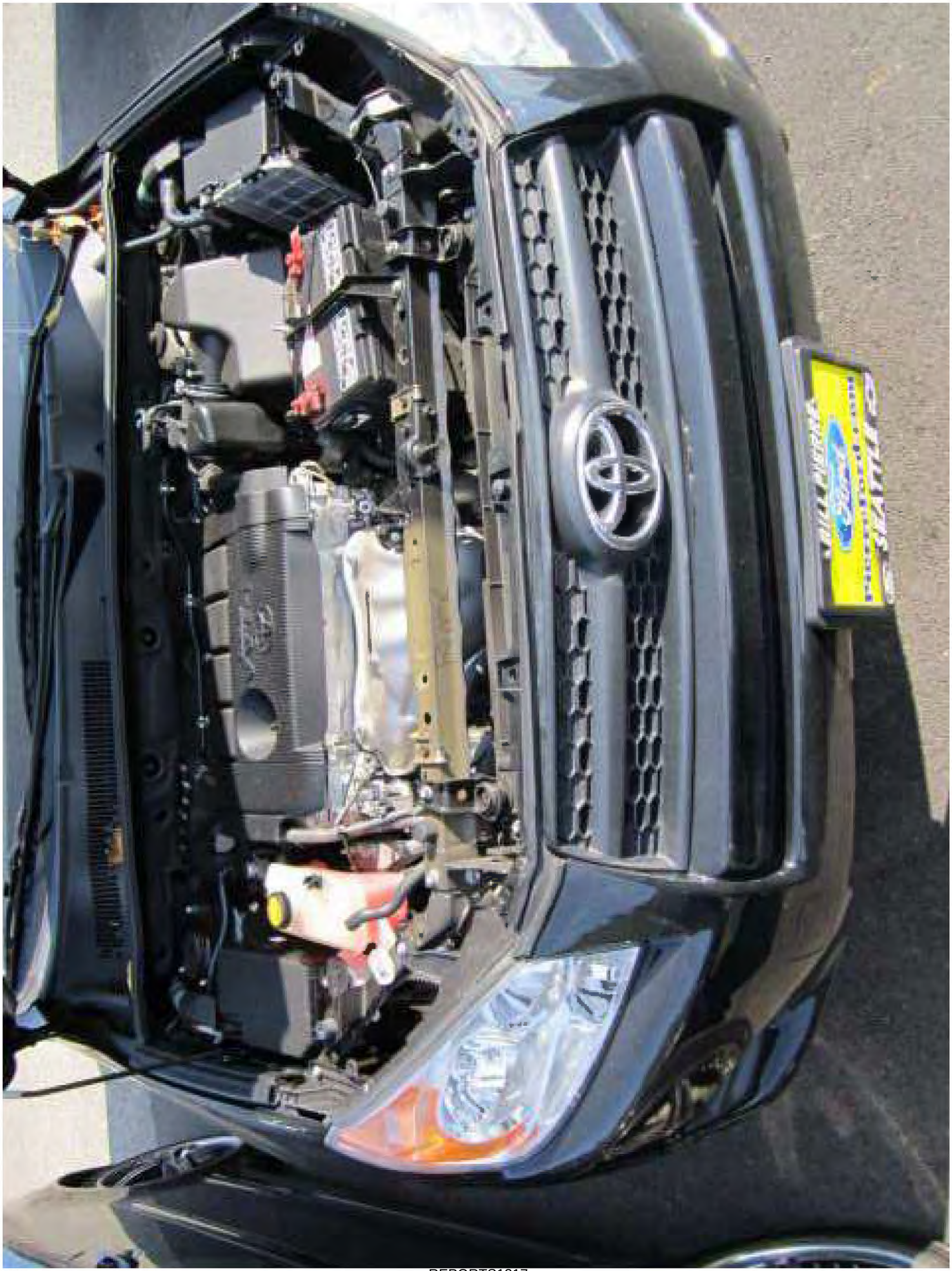

HONORABLE VERONICA ALICEA GALVÁN
Hearing Date: August 16, 2018
Without Oral Argument

IN THE SUPERIOR COURT OF THE STATE OF WASHINGTON
IN AND FOR KING COUNTY

AMELIE M. CHALAL, an individual, Plaintiff, vs. CRAIG R. MALKE, an individual, Defendant.	Case No. 17-2-18821-2 SEA **ORDER GRANTING PLAINTIFF'S MOTION TO EXCLUDE BRADLEY PROBST**

THIS MATTER comes before the Court upon Plaintiff's Motion to Exclude Bradley Probst. The Court has reviewed the court file and pleadings submitted, including the following:

1. Plaintiff's Motion for to Exclude Bradley Probst;
2. Declaration of Joseph W. Moore with exhibits;
3. Defendant's Response
4. Declaration of Joseph Kopta
5. Plaintiff's Reply

The COURT hereby FINDS that:

Mr. Probst's opinions exceed his qualifications as he intends to testify as to the causes, or lack of cause, of Plaintiff's injuries.

MOORE LAW GROUP, PLLC
2722 Colby Avenue, Suite 607
Everett, WA 98201
P: (425) 998-8999 / F: (425) 903-3638

Mr. Probst's opinions are inadmissible under ER 702, as they are unhelpful to the trier of fact.

Mr. Probst's opinions are inadmissible under ER 403 as they are unfairly prejudicial, confusing, and likely to mislead the jury.

The COURT therefore ORDERS as follows:

Plaintiff's motion to exclude Bradley Probst is **GRANTED**.

DONE in open court this 20 day of August, 2018.

HONORABLE VERONICA ALICEA GALVAN

MOORE LAW GROUP

Joseph W. Moore, WSBA No. 44061
Attorney for Plaintiff

Approved as to form;
Notice of Presentation Waived By:

KOPTA & MACPHERSON

Joseph R. Kopta, WSBA No. 17682
James E. Macpherson, WSBA No. 8952
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August 17, 2018

Michael Amaro, Esquire
Amaro Baldwin
180 E. Ocean Blvd.
Suite 850
Long Beach, CA 90802

Re: *Hollingshead, Barbara v. PetSmart, Inc.*
ARCCA Case No.: 5468-001

agree forces from fall, give rise to hand & shoulder injuries

Dear Mr. Amaro:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Barbara Hollingshead. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us. Did you get

explain what

The opinions given in this report are based on my analysis of the what materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

what does automotive industry have to do w/ our case

I have ? designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

no what → I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential. car crashes

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1 Nahum, A., Gomez, M., (1994) Injury Reconstruction: The Biomechanical Analysis of Accidental Injury, (SAE 940568). Warrendale, PA, Society of Automotive Engineers.

2 Siegmund, G., King, D., Montgomery, D., (1996) Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

3 Robbins, D.H., et al., (1983) Biomechanical Accident Investigation Methodology Using Analytic Techniques, (SAE 831609). Warrendale, PA, Society of Automotive Engineers.

4 King, A.I., (2000) "Fundamentals of Impact Biomechanics: Part I – Biomechanics of the Head, Neck, and Thorax." Annual Reviews in Biomedical Engineering, 2:55-81.

5 King, A.I., (2001) "Fundamentals of Impact Biomechanics: Part II – Biomechanics of the Abdomen, Pelvis, and Lower Extremities." Annual Reviews in Biomedical Engineering, 3:27-55.

$ as far as injury from our fall

car crashes

ARCCA INCORPORATED

Incident Description:

discuss

According to the available information, on August 21, 2017, Ms. Barbara Hollingshead entered the PetSmart located at 17845 Garden Way NE in Woodinville, Washington. Upon crossing the threshold of the outer doors, Ms. Hollingshead tripped and fell in the foyer. what did she trip on?

Information Reviewed:

In the course of my analysis, I reviewed the following materials: WHO | WHAT | WHERE | WHEN (WHY | HOW)

- Video surveillance footage of the subject incident 6 GOOD FRIENDS
- Complaint for Damages, *Barbara Hollingshead vs. PetSmart, Inc.* [December 21, 2017] WHAT DOES THIS DO FOR YOU
- Human Factors Analysis report prepared by Gary D. Sloan, Ph.D. [July 26, 2018]
- Deposition transcript of Tennessee Sandeaux, *Barbara Hollingshead vs. PetSmart, Inc.* [April 27, 2018] HOW SIGNIFICANT
- Deposition transcript of Barbara S. Hollingshead, *Barbara Hollingshead vs. PetSmart, Inc.* [June 13, 2018]
- Scene inspection photographs WHO | WHAT | WHERE ARE THEY
- Inspection of the PetSmart store, August 8, 2018 WHO W/ YOU; HOW MUCH TIME
- Inspection of the shoes worn by Ms. Hollingshead at the time of the subject incident, August 8, 2018 WHO | WHEN | WHAT DID YOU DO
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards TELL ME WHAT RELEVANT LITERATURE

Biomechanical Analysis:

The scope of my investigation in this matter entailed an analysis of Ms. Barbara Hollingshead's subject fall incident to determine, if possible, the most likely scenario(s) from the realm of possible scenarios. In doing so, my analysis employed the scientific methodology of ruling in or out various scenarios by considering the facts of the case in conjunction with my findings and the fundamental principles of human factors, human movement/injury biomechanics, national building codes, standards, and design practices. [6,7,8,9,10,11,12,13,14,15,16,17]

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6 Winter, D.A. (1990). Biomechanics and motor control of human movement. John Wile & Sons, Inc. New York, NY.

7 Hay, J.G. and Reid, J.G. (1988). Anatomy, mechanics and human motion. 2nd edition. Prentice-Hall, Inc. Englewood Cliffs, NJ.

8 Sanders, M.S. and McCormick, E.J. (1993). Human factors in engineering and design; Seventh edition, McGraw-Hill, NY.

9 Chaffin, D.B and Andersson, G.B.J. (1991) Occupational biomechanics, second edition. John Wiley & Sons, New York.

10 Resnick, R. and Halliday, D. (1977). Physics. John Wiley & Sons, New York.

11 Gushue, D. L. et al. (2007). *Biomechanics for Risk Managers-Analyses of Slip, Trip & Fall Injuries*. Proceedings of the 2007 ASSE Professional Development Conference. Orlando, FL: ASSE.

12 Hay, J.G. and Reid, J.G. (1988). Anatomy, mechanics and human motion. 2nd edition. Prentice-Hall, Inc. Englewood Cliffs, NJ.

13 Joganich T. (2006). *Biomechanical Analysis in Slip, Trip, Stumble, and Fall Incidents*. Proceedings of the 2006 ASSE Professional Development Conference. Seattle, WA: ASSE.

14 Nahum, A.M. and Gomez, M.A. (1994). Injury reconstruction: biomechanical analysis of accidental injury. Society of Automotive Engineers, Warrendale, PA. SAE Paper No. 940568.

15 Perry, J. (1992). Gait Analysis Normal and Pathological Function. SLACK Inc., Thorofare, NJ

16 Nordin, M. and Frankel, V. H. (2001). Basic Biomechanics of the Musculoskeletal System. Third Edition. Lippincott Williams & Wilkins, Philadelphia, Pennsylvania.

17 2006 International Code Council- International Building Codes

Incident Description:

Video surveillance of the subject incident depicts Ms. Hollingshead approaching the outer entrance of the foyer for PetSmart (Figure 1). Ms. Hollingshead testified that she was looking forward.

Figure 1: Screen shot of enhanced surveillance footage depicting Ms. Hollingshead entering the store foyer.

As she crosses the metal threshold, her foot appears to catch on a floor mat in the foyer, resulting in Ms. Hollingshead falling forward into the inner doors of the foyer (Figure 2).

Figure 2: Screen shot of enhanced surveillance footage depicting Ms. Hollingshead tripping over the floor mat in the store foyer.

As Ms. Hollingshead contacts the floor mat, the surveillance footage shows the right side of the mat curling upwards and temporarily folding over. Ms. Hollingshead testified that, *"as I was walking in, I had the sensation of being tripped, and that's when I went flying and hit the second set of doors"*. She further indicated that she noticed the mat was buckled after the incident, but did not know whether it was buckled prior to her entrance.

Analysis and Discussion:

Inspection of the floor mat found that the thickness of the leading edge facing the exterior of the foyer was approximately 1/8", half of the ASTM standard requiring changes in flat walking to be at or below 1/4". Ms. Hollingshead testified that she was wearing open-heeled, step-in sandals that were approximately 5 years old. The toe strap of the shoes showed signs of wear, and were in fact partially torn along the stitching (Figure 3).

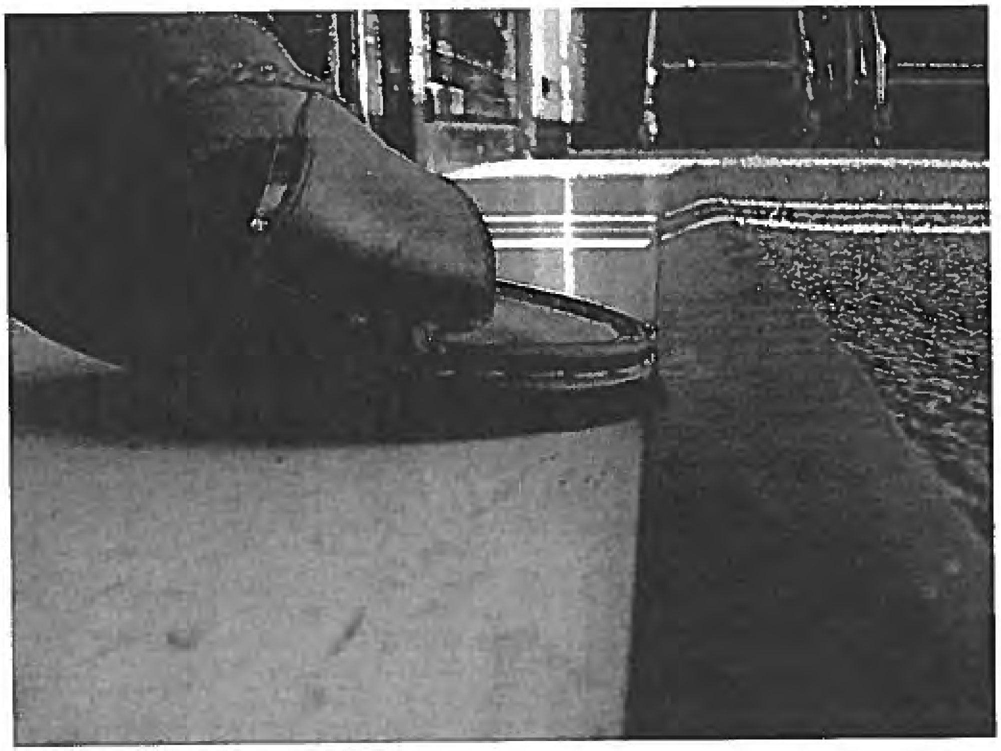

Figure 3: Photographic reproduction of Ms. Hollingshead's shoe at the subject scene.

In the report prepared by Dr. Sloan, he indicates that the sandals were *"well-worn"*, and noted, *"the straps at the toe-end of both sandals was (sic) frayed or absent"*. He concludes that despite this, the strap remained secure to the sole. However, this wear and damaged stitching would allow the sole to separate further from the strap, or for the shoe to move separately relative to Ms. Hollingshead's foot, allowing the sole to get closer to the ground during swing phase of gait than a normal shoe. Had the sole of Ms. Hollingshead's sandal been sagging during her gait, it would present a potential trip hazard over virtually any lip, including those well within the accepted ASTM standards of safety as described previously.

Dr. Sloan's report ultimately concludes that Ms. Hollingshead did not observe a tripping hazard with the floor mat, due to a raised edge, as she entered the foyer, resulting in her fall. Prior to the subject incident, surveillance footage shows multiple patrons entering and exiting through the foyer, over the floor mat, without consequence. Immediately prior to the subject incident, the floor mat shows no signs of wrinkling, or any raised sections on the leading edge at the external entrance to the foyer. After the subject incident, a wrinkle can be seen in one of the corners of the floor mat (Figure 4).

ARCCA INCORPORATED

Figure 4: Screen shot of enhanced surveillance footage comparing the floor mat before and after the subject incident. Note: annotations added for clarity.

The absence of the wrinkle in the mat at the time of Ms. Hollingshead's entry was also noted by Dr. Sloan (*"In my opinion, the buckling of the mat that is circled in Exhibits J did not precipitate the fall incident but was a consequence of Ms. Hollingshead making physical contact with the mat"*). He further notes that multiple people entered through the foyer in a similar fashion to Ms. Hollingshead without mishap. As discussed previously, inspection of the floor mat found the lip to be well within ASTM standards for safe level walking. There is no evidence of the floor mat being altered in such a way as to increase the height of the mat off of the floor, and therefore no evidence of a trip hazard being present. Additionally, inspection of the floor mat determined that as little as 3 lbs. of force would be sufficient to lift the floor mat off the ground. This indicates that had Ms. Hollingshead

shuffled her foot at the leading edge of the floor mat, it would have been able to lift up and curl, as depicted in the surveillance footage.

While Dr. Sloan provides no objective evidence of the carpet having a raised edge, nor does he provide any subjective evidence, he opines that the carpet would need to be raised a minimum of 0.5" to produce the trip and fall of Ms. Hollingshead. During my inspection of the PetSmart store and floor mat, I raised the edge of the mat 0.5" near the area where Ms. Hollingshead fell. As can be seen in Figure 5, a lifting of 0.5" is readily visible, near the middle of the photo. Again, no raised edge of the floor mat is shown in the surveillance video.

Figure 5. Floor mat with edge raised 0.5"

As can be seen in Figure 6, the stitching on the front edge of Ms. Hollingshead's shoes allows for an additional mechanism to snag the carpet. As noted above, the shoes showed signs of age and wear and tear and would not necessarily stay secured to the sole of Ms. Hollingshead's foot and could snag the floor mat. During my inspection, I was able to repeatedly snag the floor mat when the edge was raised 0.125". Again, this value is well below the above mentioned 0.25".

Figure 6. Ms. Hollingshead's shoe

Dr. Sloan commits a fallacy of logic when he speculates that because Ms. Hollingshead fell that there must have been a 0.5" trip hazard at the edge of the floor mat. This is a formal fallacy, or a pattern of reasoning rendered invalid by a flaw in its logical structure. Specifically, the Plaintiff's argument is referred to as affirming the consequent. The structure of the argument is incorrect. The argument of affirming the consequent looks like this:

a. If P then Q
b. Q
c. Therefore P.

This is a fallacy because it does not take into account other possibilities. Here is another example.

d. If it rains, the street will be wet.
e. The street is wet.
f. Therefore, it rained.

This is a fallacy of logic because it fails to consider the other possibilities such as the street is wet due to dew or the street is wet due to someone washing it down with a hose or any other number of reasons.

This is no different than the Plaintiff's argument:

g. When there is a trip hazard involving floor mats, people fall.
h. Ms. Hollingshead fell.
i. Therefore, there must be a trip hazard due to the floor mat.

Dr. Sloan provides no analysis of any sort that rules out any other mechanism and allows him to arrive at the singular conclusion that the floor mat was raised 0.5".

Given the lack of evidence of a trip hazard, a likely scenario is that Ms. Hollingshead was wearing compromised sandals, and/or shuffled her foot as she entered the foyer, and created the fold in the mat on her own accord.

Conclusions:

Based on my findings and analysis, I have concluded, within a reasonable degree of engineering and biomechanical certainty that:

- On August 21, 2017, Ms. Hollingshead entered the foyer of a PetSmart in Woodinville, Washington.
- Ms. Hollingshead contacted the leading edge of a floor mat in the foyer, ultimately resulting in a trip and fall event.
- There is no evidence that the floor mat was raised 0.5" and created a trip hazard at the time of Ms. Hollingshead's entry into the PetSmart foyer.
- Even without a trip hazard due to a raised floor mat, Ms. Hollingshead's trip and fall event can be explained by her foot initiating contact with the floor mat improperly, due to her footwear and/or gait.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This report is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst
Senior Biomechanist

ARCCA, INCORPORATED
3455 Thorndyke Ave W, Suite 206
SEATTLE, WA 98119
PHONE 877-942-7222 FAX 206-547-0759
www.arcca.com

September 13, 2018

Riley Lovejoy, Esquire
Law Offices of Mark Dietzler
1001 4th Avenue
Suite 3300
Seattle, WA 98154

Re: *LaCourse, Amber v. Natalya Leonid and Alexander Nikityuk*
File No.: 4660 7095 5036
ARCCA Case No.: 2107-1618

Dear Mr. Lovejoy:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces involved in the incident of Amber LaCourse. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, 2(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, 3(1), 27-55.

Incident Description:

According to the available documents, on April 22, 2014, Ms. Amber LaCourse was the seat-belted driver of a 2009 Kia Optima in Lake Stevens, Washington. A 2009 Mazda Mazda3 was traveling immediately behind the subject Kia. While the subject Kia was stopped in traffic, contact was made between the rear of the subject Kia and the front of the incident Mazda.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Eleven (11) color photographic reproductions of the subject 2009 Kia Optima
- Estimate of Record for the subject 2009 Kia Optima [April 23, 2014]
- Deposition transcript for Amber R. LaCourse, *Amber LaCourse vs. Stephen H. Good Jr. et al* [April 7, 2016]
- Deposition transcript for Amber LaCourse, *Amber LaCourse vs. Stephen H. Good, Jr. et al* [July 26, 2018]
- VinLink data sheet for the subject 2009 Kia Optima
- Expert AutoStats data sheets for a 2009 Kia Optima
- Expert AutoStats data sheet for the incident 2009 Mazda Mazda3
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and repair documents of the subject 2009 Kia Optima in association with accepted scientific methodologies. [6,7]

The repair documents for the subject Kia reported damage to the rear bumper cover. The photographs depicted bolt marks to the rear bumper cover (Figure 1). There was no significant crush or displacement to the rear components of the subject vehicle.

[6] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[7] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

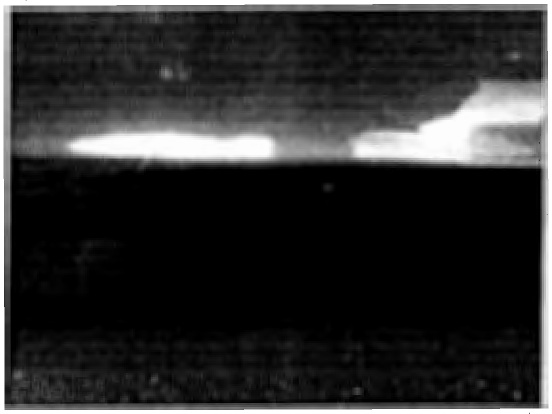

Figure 1: Reproductions of photographs of the subject 2009 Kia Optima

The Insurance Institute for Highway Safety (IIHS) performs low-speed tests on vehicles to assess the performance of the vehicles' bumpers and the damage incurred. The damage to the subject Kia Optima, defined by the photographic reproductions, and confirmed by the repair estimate, was used to perform a damage threshold speed change analysis.[8] The IIHS tested an exemplar 2009 Kia Optima in a 6.2 miles per hour (mph) rear impact into a flat barrier.[9] The test Kia sustained damage to the rear deck lid, rear body panel, rear bumper cover, rear bumper absorber, rear bumper reinforcement, and required a unibody pull. The primary damage to the subject Kia was to the rear bumper cover. Thus, because the test Kia Optima in the IIHS rear impact test sustained greater damage, the severity and energy transfer of the IIHS impact is greater compared to the severity of the subject incident. Accounting for restitution, the subject Kia experienced a Delta-V of less than 8.0 mph.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 8.0 mph Delta-V is 2.4g.[10,11,12,13] By the laws of physics, the average acceleration experienced by the subject Kia Optima in which Ms. LaCourse was seated was less than 2.4g.

Comparatively, hard braking generates approximately 0.7g to 0.8g during the event. The acceleration experienced due to gravity is 1g. This means that a person experiences 1g of loading while in a sedentary state. Therefore, Ms. LaCourse experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[14] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight.

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8 Siegmund, G.P., et al., (1996) Using *Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions*, (SAE 960887). Warrendale, PA, Society of Automotive Engineers.

9 Insurance Institute for Highway Safety Low-Speed Crash Test Report. 2006 Kia Optima, May 2007.

10 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

11 Anderson, R.A., W.J.B., et al. (1998). *Effect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

12 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

13 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

14 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

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Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. LaCourse testified that she was unaware of the oncoming impact, and was looking forward with her hand on the steering wheel. She stated that she turned the wheel with her left hand at impact, and *"punched"* the radio with her right hand. She confirmed that the damage to the Kia was *"just his license plate screws, really"*.

The laws of physics dictate that when the subject Kia Optima was contacted in the rear, it would have been pushed forward causing Ms. LaCourse's seat to move forward relative to her body. This motion would result in Ms. LaCourse moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. LaCourse's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. LaCourse was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. LaCourse's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. LaCourse would have been limited to well within the range of normal physiological limits.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[15,16,17,18] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[19] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[20,21]

Studies by Rohlmann et al.[22,23,24] have shown that seemingly benign tasks such as flexion of the upper body while standing, or crouching and arching the back, along with body position changes and lifting/laying down a weight can generate loads that are comparable to or greater than those resulting

15 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

16 Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts.* (No. 940532). SAE Technical Paper.

17 Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles.* (No. 970394). SAE Technical Paper.

18 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

19 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

20 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

21 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts.* (No. 2010-01-0141). SAE Technical Paper.

22 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

23 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

24 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

from the subject incident. Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[25] Additionally, Ng, et al, studied lumbar accelerations during activities of daily living and found accelerations ranging from 1.14 to 7.52g for activities such as sitting, walking, and jumping off a step. Further studies demonstrated thoracic and lumbar spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[26]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On April 22, 2014, Ms. Amber LaCourse was the seat-belted driver of a 2009 Kia Optima stopped in Lake Stevens, Washington, when contact occurred between the rear of the Kia and the front of a 2009 Mazda Mazda3 at a low speed.
2. The severity of the rear impact during the subject incident was below 8.0 miles per hour with an average acceleration less than 2.4g.
3. Had there been enough energy transferred to cause any motion, the 2009 Kia Optima would have been accelerated and pushed forward, coupling the occupant's motion to the vehicle, and causing the body to load into the seat and seatback.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

Bradley W. Probst, MSBME
Senior Biomechanist

25 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

26 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

ARCCA INCORPORATED

BRADLEY W. PROBST, M.S.B.M.E.

PROFESSIONAL BIOGRAPHICAL OUTLINE

BACKGROUND

Mr. Probst earned a B.S. in Mechanical Engineering at University of Louisiana, Lafayette, Louisiana, and an M.S. in Biomedical Engineering at Tulane University, New Orleans, Louisiana. For his Ph.D. research at Tulane, Mr. Probst developed the most advanced kinematic model of the human cervical spine known to date. This unique model will be used to make technological advances to Naval pilot ejection and recovery systems. In addition, Mr. Probst has also done advanced course work in the fields of biomaterials, materials engineering, biosolid mechanics, mechanisms of bodily functions, and advanced finite element analysis. He has also lectured extensively and shared teaching responsibilities for courses in biomedical engineering and design and analysis at Tulane University.

As a biomedical consultant for a national accident investigation firm and while a student, Brad gained valuable experience in forensic analysis while working on a university project to research soft tissue injury caused by dynamic inertial loading.

While investigating and presenting work on bone morphology, his focus was the proper use of computation modeling as it related to bone material property identification. His significant contributions led to important developments in the field of bone mechanics and response of living bone to stress and disease.

SUMMARY OF EXPERIENCE

- Developed his skills in mechanical engineering while acting as project engineer at a petrochemical facility, where he was responsible for several multimillion-dollar expansion and renovation projects
- Pursued graduate research on a federally funded project to investigate spinal trauma and human head and neck tolerances to dynamic impact loadings
- Performed finite element analysis, computer modeling, material testing and data analysis
- Used advanced numerical methods for model validation
- Operated state-of-the-art high-speed computers to develop his calibrated model and to validate biofidelity
- Created an accurate biofidelic model of the kinematic response of the human head and neck during any general 3D acceleration through the development of a finite element model. The conclusions and results of this important project will be used to make technological advances toward improving the safety of pilots during ejection and major recovery system improvements
- Uses his biomedical and mechanical engineering skills to analyze the relationship of crash injuries to crash forces, occupant kinematics, and human tolerance
- Uses forensic investigation and accident reconstruction techniques to develop injury mitigation devices

AREAS OF SPECIALTY

- Biomechanical Consulting
- Human Injury Tolerance
- Vehicular Accident Reconstruction
- Impact and Inertial Trauma Analysis
- Injury Mechanism and Mitigation Analysis
- Slip and Fall Analysis

ACADEMIC BACKGROUND

- Tulane University, New Orleans, LA, Ph.D. Candidate, Biomedical Engineering
- Tulane University, New Orleans, LA, M.S., Biomedical Engineering, 1996
- University of Louisiana, Lafayette, LA, B.S., Mechanical Engineering, 1988

PROFESSIONAL EXPERIENCE

January 2000 – Present | ARCCA, Incorporated | Senior Biomechanist

- Specializes in injury analysis, injury mechanism determination and crash kinematics
- Practices biomechanics to explore the cause, nature and severity of injuries
- Utilizes medical records, testing, computer modeling and his extensive knowledge of human injury tolerance to determine whether a claimed injury is consistent with a specific set of actions or exposure to a specific accident environment

1995 – 2000 | Tulane University | Research Assistant

- Pursued graduate research on a spinal trauma investigation and analysis project funded by the Office of Naval Research. His position was secured, fully funded and compensated through competitive selection
- Performed finite element analysis, computer modeling, material testing, and data analysis to develop biofidelic human cervical spine analog
- Utilized advanced numerical methods for model validation
- Proposed conclusions and research results that will be used to implement technological advancements in naval pilot ejection and recovery systems

1997 – 1999 | Unified Investigations & Sciences, Inc. | Biomechanical Consultant

- Performed forensic analysis of soft tissue injury from mild impact in automotive accidents
- Determined impact levels through vehicular accident reconstruction, and compared findings to determine injury causation and severity
- Presented written conclusions to clients and provided expert testimony relative to his findings

May 1995 – 1999 | Tulane University | Teaching Assistant

- Selected by faculty mentor to assist with and share teaching responsibilities for courses such as Statics, Introduction to Biomedical Engineering and Design and Analysis
- Collaborated with mentor to plan lectures
- Prepared of course material
- Presented lectures

1988 – 1995 | Wink Engineering | Mechanical/Project Engineer

- Managed and was responsible for several multimillion-dollar expansion and renovation projects at a petrochemical facility
- Directed and performed environmental remediation (air and water)
- Recommended and implemented improvements to waste water treatment systems

PROFESSIONAL AFFILIATIONS

- Association for the Advancement of Automotive Medicine
- Society of Automotive Engineers (SAE)
- American Society of Safety Engineers (ASSE)
- American Society of Mechanical Engineers (ASME)

PUBLICATIONS

Probst, B, R. Anderson, G. Harris, R. Hart. (2007). *A Three-Dimensional Nonlinear Kinematic Finite Element Model of the Human Cervical Spine Under Dynamic Inertial Loading.* American Society of Biomechanics Biomechanics Symposium 2007, Stanford University: ASB.

Cantor, A., M. Markushewski, L. D'Aulerio, B. Benda, D. Eisentraut, **B. Probst**, L. Sicher. (2007). *Seat Design: A Risk Benefit Approach.* ASSE.

Probst, B. (Presenter). (2007). *Industrial vs. Academic Perspectives on Bioengineering Education.* ASME Summer Bioengineering Conference. Keystone, CO: ASME.

Probst, B., R. Anderson, T. Hart, G. Harris, S. Guccione. (2007). *A Three-Dimensional Nonlinear Kinematic Finite Element Model of the Human Cervical Spine Under Dynamic Inertial Loading.* American Society of Biomechanics Northwest Biomechanics Symposium 2007, Eugene, Oregon: ASB.

Markushewski, M., Gushue, D., **Probst, B.**, Coward, C., (2007). *When Driver Safety Fails—Then What? Vehicular Accident Analysis: The Big Picture.* ASSE.

Gushue, D.L., Joganich, T., **Probst. B. W.**, Markushewski, M. (2007). *Biomechanics for Risk Managers—Analysis of Slip, Trip & Fall Injuries.* ASSE.

Gushue, D., **B. Probst**, et al. (2006). *Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine during Simulated Low-Speed Rear Impacts.* Safety 2006, Seattle, WA, ASSE.

Benda, B. J., L. D'Aulerio, A. Cantor, M. L. Markushewski, **B. Probst**, et al. (2006). *Performance of Automotive Seat Belts During Inverted (-Gz) Rollover Drop Tests.* Icrash 2006—International Crashworthiness Conference, Athens, Greece, University of Bolton.

Coleman, J.C., **Probst, B.W.**, Roberts, M.D., and Hart, R.T. (1999). *Meshes Based On Cube-Shaped Finite Elements Do Not Converge: Quadratic Tetrahedral Elements Are An Alternative. Proceedings of the 1999 Summer Bioengineering Conference (ASME)* Big Sky, MT, June 1999. (pp. 329-230) New York: ASME.

Coleman, J.C., **Probst, B.W.**, Roberts, M.D., and Hart, R.T. (1998). *Investigating the Convergence Behavior of Voxel-Based Finite Element Meshes. Proceedings of the 7th Annual Symposium on Computational Methods in Orthopaedic Biomechanics*, Anaheim, CA, February 1998. Chicago: Orthopaedic Research Society (ORS).

COURSE INSTRUCTION

- *Slip/Trip/Falls*, Rocky Mountain IASIU Chapter, Denver, CO. May 7, 2009
- *Biomechanics*, Puget Sound Special Investigators, Seattle, WA. July 30, 2009
- *Slip/Trip/Falls*, Las Vegas IASIU Chapter, Las Vegas, NV. December 7, 2009
- *Low Speed Impacts*, Oregon IASIU Chapter, Portland, OR. May 4, 2010
- *Slip/Trip/Falls*, Oregon IASIU Chapter, Portland, OR. Oct 7, 2011
- *Biomechanics*, Hawaii RIMS Chapter, Honolulu, HI. September 15, 2011
- *Determining Injury Causation*, Alaska RIMS Chapter, Anchorage, AK. October 19, 2011
- *Biomechanics*, OR RIMS Chapter, Portland, OR. June 20, 2013
- *Determining Injury Causation*, Los Angeles RIMS Chapter, September 17, 2014

OTHER PROFESSIONAL ACTIVITIES

Judge at the Edmonds Annual Hot Autumn Nites Car Show, Edmonds, WA, September 6, 2008 sponsored by the Greater Edmonds Chamber of Commerce

ARCCA, INCORPORATED
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October 5, 2018

Benjamin Miller, Esquire
Law Office of Alice C. Brown
130 Nickerson Street
Suite 305
Seattle, WA 98109

Re: *Prescott, Patricia v. Michelle Kim and William Lee*
ARCCA Case No.: 3240-805

Dear Mr. Miller:

Thank you for the opportunity to participate in the above-referenced matter. Your firm retained ARCCA, Incorporated to evaluate the subject incident in relation to the forces and claimed biomechanical failures involved in the incident of Patricia Prescott. This analysis is based on information currently available to ARCCA. However, ARCCA reserves the right to supplement or revise this report if additional information becomes available to us.

The opinions given in this report are based on my analysis of the materials available, using scientific and biomechanical methodologies generally accepted in the automotive industry.[1,2,3,4,5] The opinions are also based on my education, background, knowledge, and experience in the fields of human kinematics and biomechanics. I have a Bachelor of Science degree in Mechanical Engineering, a Master of Science degree in Biomedical Engineering, and have completed the educational requirements for my Doctor of Philosophy degree in Biomedical Engineering. I am a member of the Society of Automotive Engineers, the Association for the Advancement of Automotive Medicine, the American Society of Safety Engineers, and the American Society of Mechanical Engineers.

I have designed, developed, and tested kinematic models of the human cervical spine and head. My testing and research have been performed with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of human tolerance to inertial and impact loading, as well as the techniques and processes for evaluating human kinematics and biomechanical failure potential.

I have designed, developed, and tested seating and restraint systems. I performed my testing and research with both anthropomorphic test devices and human subjects. As such, I am very familiar with the theory and application of restraint systems and their ability to protect occupants from inertial and impact loading, as well as the techniques and processes for evaluating their performance and biomechanical failure potential.

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1 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

2 Siegmund, G., King, D., Montgomery, D. (1996). *Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions* (No. 960887). SAE Technical Paper.

3 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

4 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

5 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

Incident Description:

According to the available documents, on December 8, 2014, Ms. Patricia Prescott was the seat-belted driver of a 1991 Honda Accord traveling in Federal Way, Washington. Ms. Michelle Kim was the driver of a 2003 Audi Allroad Quattro traveling immediately behind the subject Honda Accord. While stopped in traffic, contact was made between the rear of the subject Honda and the front of the incident Audi.

Information Reviewed:

In the course of my analysis, I reviewed the following materials:

- Defendant's Interrogatories, *Patricia Prescott vs. Michelle Kim* [May 16, 2018]
- Nine (9) color photographic reproductions of the subject 1991 Honda Accord
- Twenty-one (21) color photographic reproductions of the incident 2003 Audi Allroad Quattro
- Estimate of Record for the subject 1991 Honda Accord [August 4, 2015]
- Estimate of Record for the incident 2003 Audi Allroad Quattro [December 17, 2014]
- Supplement of Record 1 for the incident 2003 Audi Allroad Quattro [January 12, 2015]
- Supplement of Record 2 for the incident 2003 Audi Allroad Quattro [January 29, 2015]
- Deposition transcript from Patricia Prescott [June 15, 2018]
- Deposition transcript from Michelle Kim [June 15, 2018]
- IME Report from Dr. John Burns, *Prescott v. Kim & Lee* [September 24, 2018]
- VinLink data sheet for the subject 1991 Honda Accord
- Expert AutoStats data sheets for a 1991 Honda Accord
- VinLink data sheet for the incident 2003 Audi Allroad Quattro
- Expert AutoStats data sheets for a 2003 Audi Allroad Quattro
- Publicly available literature, including, but not limited to, the documents cited within this report, learned treatises, text books, technical journals, and scientific standards.

Biomechanical Analysis:

The method used to conduct a biomechanical analysis is well defined and accepted in the scientific community and is an established approach to assessing biomechanical failure causation as documented in the technical literature.[6,7,8,9,10] Within the context of this incident, my analyses consisted of the following steps:

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6 Robbins, D.H., Melvin, J.W., Huelke, D.F., & Sherman, H.W. (1983). *Biomechanical accident investigation methodology using analytical techniques* (No. SAE 831609). SAE Technical Paper.

7 Nahum, A.M., & Gomez, M.A. (1994). *Injury Reconstruction: The Biomechanical Analysis of Accidental Injury* (No. 940568). SAE Technical Paper.

8 King, A.I. (2000). Fundamentals of Impact Biomechanics: Part I-Biomechanics of the Head, Neck, and Thorax. *Annual Review of Biomedical Engineering*, *2*(1), 55-81.

9 King, A.I. (2001). Fundamentals of Impact Biomechanics: Part II-Biomechanics of the Abdomen, Pelvis, and Lower Extremities." *Annual Review of Biomedical Engineering*, *3*(1), 27-55.

10 Whiting, W. C., & Zernicke, R. F. (2008). *Biomechanics of Musculoskeletal Injury*. Human Kinetics.

1. Identify the biomechanical failures that Ms. Prescott claims were caused by the subject incident on December 8, 2014;
2. Quantify the nature of the subject incident in terms of the forces, accelerations, and changes in velocity of the subject 1991 Honda Accord;
3. Determine Ms. Prescott's kinematic responses within the vehicle as a result of the subject incident;
4. Define the biomechanical failure mechanisms known to cause the reported biomechanical failures and determine whether the defined biomechanical failure mechanisms were created during the subject incident;
5. Evaluate Ms. Prescott's personal tolerances in the context of her pre-incident condition to determine to a reasonable degree of scientific certainty whether a causal relationship exists between the subject incident and her reported biomechanical failures.

If the subject incident created the biomechanical failure mechanisms that generate the reported biomechanical failures, a causal link between the biomechanical failures and the event cannot be ruled out. If, the subject incident did not create the biomechanical failure mechanisms associated with the reported biomechanical failures, then a causal link to the subject incident cannot be established.

Biomechanical Failure Summary:

The available documents indicate Ms. Prescott attributes the following biomechanical failures as a result of the subject incident:

- Cervical Spine
    - Sprain/strain
- Thoracolumbar Spine
    - Scoliosis

Damage and Incident Severity:

The severity of the incident was analyzed by using the photographic reproductions and available repair estimates of the subject 1991 Honda Accord and the incident 2003 Audi Allroad Quattro in association with accepted scientific methodologies. [11,12]

The repair estimate for the subject 1991 Honda Accord reported damage to the rear bumper cover. The available photographs depicted small scrapes to the rear bumper cover (Figure 1).

[11] Siegmund, G.P., et al., (1996). Using Barrier Impact Data to Determine Speed Change in Aligned, Low-Speed Vehicle-to-Vehicle Collisions (SAE 960887). Warrendale, PA, Society of Automotive Engineers

[12] Bailey, M.N., Wong, B.C., and Lawrence, J.M., (1995). Data and Methods for Estimating the Severity of Minor Impacts (SAE 950352). Warrendale, PA, Society of Automotive Engineers.

Figure 1: Reproductions of photographs of the subject 1991 Honda Accord

The repair documents for the incident 2003 Audi Allroad Quattro indicated there was damage to the front bumper cover, license bracket, left trim, left/right trim rivet, left/right energy absorber, and hood. The photographs depicted no residual crush to the front bumper structures (Figure 2).

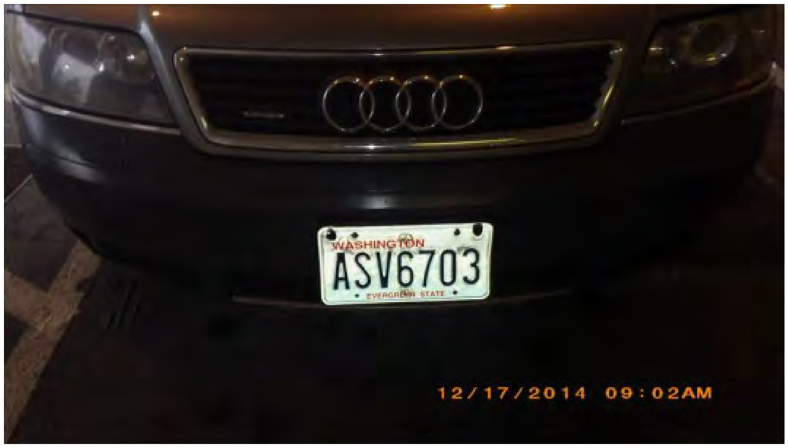

Figure 2: Reproductions of photographs of the incident 2003 Audi Allroad Quattro

Energy-based crush analyses have been shown to represent valid and accurate methods for determining the severity of automobile collisions.[13,14,15,16,17] Analyses of the photograph and geometric measurements along with the repair record of the subject 1991 Honda Accord revealed the damage due to the subject incident. An energy crush analysis[18] indicates that a single 10 mile per hour flat barrier impact to the rear of an exemplar Honda Accord would result in significant and visibly noticeable crush across the entirety of the subject Honda's rear structure, with a residual crush of 3 inches. Therefore, the energy crush analysis shows significantly greater deformation would occur in a 10 mile per hour Delta-V (the Delta-V is the change in velocity of the vehicle from its pre-impact, initial velocity, to its post-impact velocity) impact than that of the subject incident.[19] The lack of significant structural crush to the entire rear of the subject Honda indicates a collision resulting in a Delta-V significantly below 10 miles per hour.

13 Campbell, K.L. (1974). *Energy Basis for Collision Severity*. (No. 740565). SAE Technical Paper.
14 Day, T.D. and Siddall, D.E. (1996). *Validation of Several reconstruction and Simulation Models in the HVE Scientific Visualization Environment*. (No. 960891). SAE Technical Paper.
15 Day, T.D. and Hargens, R.L. (1985). *Differences Between EDCRASH and CRASH3*. (No. 850253). SAE Technical Paper.
16 Day, T.D. and Hargens, R.L. (1989). *Further Validation of EDCRASH Using the RICSAC Staged Collisions*. (No. 890740). SAE Technical Paper.
17 Day, T.D. and Hargens, R.L. (1987). *An Overview of the Way EDCRASH Computes Delta-V*. (No. 870045). SAE Technical Paper.
18 EDCRASH, Engineering Dynamics Corp.
19 Tumbas, N.S., Smith, R.A., (1988) Measuring Protocol for Quantifying Vehicle Damage from an Energy Basis Point of View, (SAE 880072). Warrendale, PA, Society of Automotive Engineers.

Furthermore, the IIHS tested multiple vehicles of the same era from the same manufacturer as the subject vehicle, as well as vehicles from other manufacturers. In a 5 mile-per-hour front impact into a barrier, the test vehicles sustained damage comparable if not greater to the damage sustained on the subject Honda. The primary damage to the subject Honda was only cosmetic in nature. Thus, because the test vehicles in the IIHS front impact tests sustained comparable damage, the severity of the IIHS impact is comparable to the severity of the subject incident and places the subject incident speed at the test speed of 5 miles per hour.

Using an acceleration pulse with the shape of a haversine and an impact duration of 150 milliseconds (ms), the average acceleration associated with a 10 mile-per-hour Delta-V is 3.0g and 1.5g for a 5 mile-per-hour Delta-V.[20,21,22,23] By the laws of physics, the average acceleration experienced by the subject Honda Accord in which Ms. Prescott was seated was significantly less than 3.0g and more consistent with 1.5g.

The acceleration experienced due to gravity is 1g. This means that Ms. Prescott experiences 1g of loading while in a sedentary state. Therefore, Ms. Prescott experiences an essentially equivalent acceleration load on a daily basis while in a non-sedentary state as compared to the subject incident. The joints of the human body are regularly and repeatedly subjected to a wide range of forces during daily activities. Almost any movements beyond a sedentary state can result in short duration joint forces of multiple times an individual's body weight. Events, such as slowly climbing stairs, standing on one leg, or rising from a chair, are capable of such forces.[24] More dynamic events, such as running, jumping, or lifting weights, can increase short duration joint load to as much as ten to twenty times body weight. Yet, because of the remarkable resiliency of the human body, these joints can undergo many millions of loading cycles without significant degeneration.

Kinematic Analysis:

Ms. Prescott's medical records indicated she was 65 inches in height, weighed approximately 113 lbs., and was 64 years old at the time of the subject incident. Ms. Prescott testified that she was stopped and waiting to turn left. She also testified that "much to my surprise, I was rear ended," but she did not hit her head or lose consciousness. The lack of head contact is consistent with the subject incident being of lower severity.

The laws of physics dictate that when the subject Honda Accord was contacted in the rear, it would have been pushed forward causing Ms. Prescott's seat to move forward relative to her body. This motion would result in Ms. Prescott moving rearward relative to the interior of the subject vehicle and loading into the seatback structures. Ms. Prescott's torso and pelvis would settle back into the seatback and seat bottom cushions. The available documents indicated Ms. Prescott was wearing the available three point restraint. Any rebound would have been within the range of protection afforded by the available restraint system and coupled Ms. Prescott's body to the seat structures. The restraint provided by the seatback and seat belt system were such that any motion of Ms. Prescott would have been limited to well within the range of normal physiological limits.

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20 Agaram, V., et al. (2000). *Comparison of Frontal Crashes in Terms of Average Acceleration*. (No. 2000-01-0880). SAE Technical Paper.

21 Anderson, R.A., W.J.B., et al. (1998). E*ffect of Braking on Human Occupant and Vehicle Kinematics in Low Speed Rear-end Collisions*. (No. 980298). SAE Technical Paper.

22 Tanner, B.C., Chen, F.H, Wiechel, J.F., et al. (1997). *Vehicle and Occupant Response in Heavy Truck to Car Low-Speed Rear Impacts*. (No. 970120). SAE Technical Paper.

23 Tanner, C.B., Wiechel, J.F., Bixel, R.A., and Cheng, P.H. (2001). *Coefficients of Restitution for Low and Moderate Speed Impacts with Non-Standard Impact Configurations*. (No. 2001-01-0891). SAE Technical Paper.

24 Mow, V.C. and Hayes, W.C. (1991). Basic Orthopaedic Biomechanics. Raven Press, New York.

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Evaluation of Biomechanical Failure Mechanisms:

Based upon the review of the damage to the subject vehicle and the available incident data, the relevant crash severity resulted in accelerations well within the limits of human tolerance and typically within the range of normal, daily activities. The energy imparted to Ms. Prescott was well within the limits of human tolerance and well below the acceleration levels that she likely experienced during normal daily activities. Without exceeding these limits, or the normal range of motion, there is no biomechanical failure mechanism present to causally link her reported biomechanical failures and the subject incident.[25,26]

From a biomechanical perspective, causation between an alleged incident and a claimed biomechanical failure is determined by addressing two issues or questions:

1. Did the subject incident load the body in a manner known to cause damage to a body part? That is, did the subject event create a known biomechanical failure mechanism?
2. If a biomechanical failure mechanism was present, did the subject event load the body with sufficient magnitude to exceed the tolerance or strength of the specific body part? That is, did the event create a force sufficiently large to cause damage to the tissue?

A sprain is a biomechanical failure which occurs to a ligament (a thick tough, fibrous tissue that connects bones together) by overstretching. A strain is a biomechanical failure to a muscle, or tendon, in which the muscle fibers tear as a result of overstretching. Therefore, to sustain a strain/sprain type biomechanical failure to any tissue, significant motion, which produces stretching beyond its normal limits, must occur. If both the biomechanical failure mechanism was present and the applied loads approached or exceeded the tolerance of the body part, then a causal relationship between the subject incident and the claimed biomechanical failures cannot be ruled out. If, however, the biomechanical failure mechanism was not present or the applied loads were small compared to the strength of the effected tissue, then a causal relationship between the subject incident and the biomechanical failures cannot be made.

Cervical Spine

According to the IME report, Ms. Prescott was diagnosed with a cervical sprain/strain. The symptoms of a sprain/strain are consistent with muscle discomfort and do not necessarily indicate a physical change such as overstretching or tearing. This report addresses a biomechanical sprain/strain as defined above and not simple muscle discomfort.

There is no reason to assume that the claimed cervical biomechanical failures are causally related to the subject incident. In a rear impact that produces motion of the subject vehicle, the Honda Accord would be pushed forward and Ms. Prescott would have moved rearward relative to the vehicle, until her motion was stopped by the seatback and seat bottom. Examination of an exemplar 1991 Honda Accord revealed that the nominal height of the front seat with an unoccupied, uncompressed seat is 30.5 inches in the full down position, and 32.0 inches in the full up position. In addition, the seat bottom cushion will compress approximately two inches under the load of an occupant. Performing an anthropometric regression of Ms. Prescott revealed she would have a normal seated height of 32.6 inches. Thus, the seatback and headrest support and the low vehicle accelerations during the subject incident designate that Ms. Prescott's cervical spine would have undergone only a subtle degree of

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25 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

26 Mertz, H.J. and Patrick, L.M. (1971). *Strength and Response of The Human Neck*. (No. 710855). SAE Technical Paper.

the characteristic response phases.[27] The load would have been applied predominantly horizontal to her cervical spine and minimized relevant cervical loads.[28] The cervical loads were within physiologic limits and Ms. Prescott would not have been exposed to a cervical spine biomechanical failure mechanism during the subject incident.[29,30,31]

Several researchers have conducted human volunteers rear impact studies with accelerations at levels comparable to and greater than that of the subject incident.[32,33,34,35,36] The test subjects consistently moved toward the impact, rearward in this case, relative to the vehicle's interior until settling into the seatback structures. None of the volunteers reported cervical biomechanical failures, and the occupant kinematics were inconsistent with the mechanism for cervical biomechanical failures. Note: several of these volunteers were diagnosed with pre-existing degenerative conditions within the cervical spine. In addition, previous research has reported that even in the absence of a head restraint, the cervical spine sprain/strain biomechanical failure threshold is 5g.[37] Additional studies at severity levels comparable to that of the subject incident, cadaveric and anthropomorphic test device (ATD) experimentation failed to produce cervical trauma and kinematics were inconsistent with the mechanism for cervical biomechanical failure.

The human body experiences accelerations, arising from common events, of multiple times body weight without significant detrimental outcome. Multiple studies have shown that daily activities ranging from plopping into a chair to a simple head shake produce head and cervical accelerations comparable to or greater than the subject incident. More dynamic activities such as a vertical leap produce even higher peak head accelerations, up to 4.75g.[38,39,40,41] The available documents reported Ms. Prescott was capable of performing regular daily activities. Additional research has shown that

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27 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

28 Welch, T., Bridges, A.W., Gates, D.H., et al., (2010). An Evaluation of the BioRID II and Hybrid III during Low- and Moderate-Speed Rear Impact (SAE 2010-01-1031). Warrendale, PA, Society of Automotive Engineers.

29 Maiman, D.J., Sances, A., Myklebust, J.B., et al. (1983). "Compression Injuries of the Cervical Spine: A Biomechanical Analysis." Neurosurgery. 13(3): 254-260.

30 Myers, B.S., McElhaney, J.H., Richardson, W.J., (1991). The Influence of End Condition on Human Cervical Spine Injury Mechanisms, (SAE 912915) Warrendale, PA, Society of Automotive Engineers.

31 Stemper, B.D., Yoganandan, N., Pintar, F.A., et al. (2011). "The Relationship Between Lower Neck Shear Force and Facet Joint Kinematics during Automotive Rear Impacts." Clinical Anatomy 24: 319-326.

32 Mertz, H.J. and Patrick, L.M. (1967). *Investigation of The Kinematics and Kinetics of Whiplash*. (No. 670919). SAE Technical Paper.

33 West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

34 Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

35 Szabo, T.J., Welcher, J.B., et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

36 Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

37 Ito, S., Ivancic, P.C., Panjabi, M.M., & Cunningham, B.W. (2004). Soft tissue injury threshold during simulated whiplash: a biomechanical investigation. *Spine*, *29*(9), 979-987.

38 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

39 Ng, T.P., Bussone, W.R., & Duma, S.M. (2005). The effect of gender and body size on linear accelerations of the head observed during daily activities. *Biomedical Sciences Instrumentation*, *42*, 25-30.

40 Funk, J.R., Cormier, J.M., et al. (2007). An Evaluation of Various Neck Injury Criteria in Vigorous Activities. *International Research Council on the Biomechanics of Impact,* 233-248.

41 Funk, J.R., Cormier, J.M., Bain, C.E., Guzman, H., Bonugli, E., & Manoogian, S.J. (2011). Head and neck loading in everyday and vigorous activities. *Annals of Biomedical Engineering*, *39*(2), 766-776.

cervical spine accelerations during activities of daily living are comparable to or greater than the accelerations associated with the subject incident.[42]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the subject incident created accelerations that were well within the limits of human tolerance and were comparable to a range typically seen during normal, daily activities. As this crash event did not create forces that exceeded the limits of human tolerance, a causal link between the subject incident and the reported cervical spine biomechanical failures of Ms. Prescott cannot be made.

Thoracic and Lumbar Spine

According to the IME report, Ms. Prescott was diagnosed with longstanding thoracolumbar scoliosis. The subject incident did not generate enough force or movement to cause anatomical deformation that would lead to scoliosis or exacerbate an already existing condition.

During an event such as the subject incident, the thoracic and lumbar spine of Ms. Prescott is well supported by the seat and seatback. This support prevents biomechanical failure motions or loading of Ms. Prescott's thoracic and lumbar spine. The seatback would limit the range of movement to well within normal levels; no kinematic biomechanical failure mechanisms are created. The seatback would also distribute the restraint forces over the entire torso, limiting both the magnitude and direction of the loads applied to the thoracic and lumbar spine. The lack of relative motion would indicate a lack of compressive, tensile, shear, or torsional loads to the thoracic and lumbar spine; thus it would not be possible to load the tissue to its physiological limit where tissue failure, or biomechanical failure, would occur.

Studies using human volunteers have exposed subjects to rear-end impacts at comparable to and greater severity than the subject incident.[43,44,45,46] This testing has demonstrated occupants moved rearward relative to the vehicle's interior until supported by the seatback. None of the participants reported any spinal trauma and kinematics were inconsistent with the mechanism for thoracic and lumbar biomechanical failure. West et al. subjected human volunteers to multiple rear-end impacts with reported barrier equivalent velocities ranging from approximately 2.5 mph to 8 mph.[47] The only symptoms reported in the study were minor neck pains for two volunteers which lasted for one to two days. The authors indicated that these symptoms were the likely result of multiple impact tests. Additionally, studies have incorporated ATDs; which measured spinal response to rear impact accelerations at severities greater than the subject incident.[48,49] Ms. Prescott's thoracic and lumbar

[42] Vijayakumar, V., Scher, I., et al. (2006). *Head Kinematics and Upper Neck Loading During Simulated Low-Speed Rear-End Collisions: A Comparison with Vigorous Activities of Daily Living*. (No. 2006-01-0247). SAE Technical Paper.

[43] Castro, W.H., Schilgen, M., Meyer, S., Weber, M., Peuker, C., & Wörtler, K. (1996). Do" whiplash injuries" occur in low-speed rear impacts?. *European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, *6*(6), 366-375.

[44] Szabo, T.J., Welcher, J.B. Welcher, et al. (1994). *Human Occupant Kinematic Response to Low Speed Rear-End Impacts*. (No. 940532). SAE Technical Paper.

[45] Nielsen, G.P., Gough, J.P., Little, D.M., et al. (1997). *Human Subject Responses to Repeated Low Speed Impacts Using Utility Vehicles*. (No. 970394). SAE Technical Paper.

[46] Weiss M.S., Lustick L.S., Guidelines for Safe Human Experimental Exposure to Impact Acceleration, Naval Biodynamics Laboratory, NBDL-86R006.

[47] West, D.H., Gough, J.P., et al. (1993). Low Speed Rear-End Collision Testing Using Human Subjects. *Accident Reconstruction Journal*, *5*, 22-26.

[48] Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

[49] Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

spine would not have been exposed to any loading or motion outside of the range of her personal tolerance levels.[50,51,52,53,54]

Multiple investigations have shown that apparently benign tasks such as flexion of the upper body while standing, body position changes, lifting/laying down a weight, along with crouching and arching the back can generate loads that are comparable to or greater than those resulting from the subject incident.[55,56,57,58] Further studies of lumbar accelerations during activities of daily living found accelerations for activities such as sitting, walking, and jumping off a step to be comparable to or greater than the subject incident.[59,60] Peer-reviewed technical literature and learned treatises have demonstrated that the compressive forces experienced during typical activities of daily living, such as stretching/strengthening exercises typically associated with physical therapy, were comparable to or greater than those associated with the subject incident.[61] According to the available documents, Ms. Prescott was capable of performing daily activities. A segmental analysis of Ms. Prescott demonstrated that as she lifted objects during daily tasks, the forces applied to her lower spine would have been comparable to or greater than those during the subject incident.[62,63,64]

Based upon the review of the available incident data and the results cited in the technical literature as described above, the kinematics or occupant motions caused by this incident were well within the normal range of motion associated with the thoracic and lumbar spine. Finally, the forces created by the incident were well within the limits of human tolerance for the thoracic and lumbar spine and were within the range typically seen in normal, daily activities. As this crash event did not create the required biomechanical failure mechanism and did not create forces that exceeded the personal tolerance limits of Ms. Prescott, a causal link between the subject incident and claimed thoracic and lumbar biomechanical failures cannot be made.

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50 Gushue, D.L., Probst, B.W., Benda, B., Joganich, T., McDonough, D., & Markushewski, M.L. (2006). Effects of Velocity and Occupant Sitting Position on the Kinematics and Kinetics of the Lumbar Spine During Simulated Low-Speed Rear Impacts. In *ASSE Professional Development Conference and Exposition*. American Society of Safety Engineers.

51 Nordin, M. and Frankel, V.H. (1989). Basic Biomechanics of the Musculoskeletal System. Lea & Febiger, Philadelphia, London.

52 Adams, M.A., & Hutton, W.C. (1982). Prolapsed intervertebral disc: a hyperflexion injury. *Spine*, *7*(3), 184-191.

53 Schibye, B., Søgaard, K., Martinsen, D., & Klausen, K. (2001). Mechanical load on the low back and shoulders during pushing and pulling of two-wheeled waste containers compared with lifting and carrying of bags and bins. *Clinical Biomechanics*, *16*(7), 549-559.

54 Gates, D., Bridges, A., Welch, T.D.J., et al. (2010). *Lumbar Loads in Low to Moderate Speed Rear Impacts*. (No. 2010-01-0141). SAE Technical Paper.

55 Rohlmann, A., Claes, L.E., Bergmann, G., Graichen, F., Neef, P., & Wilke, H.J. (2001). Comparison of intradiscal pressures and spinal fixator loads for different body positions and exercises. *Ergonomics*, *44*(8), 781-794.

56 Rohlmann, A., Petersen, R., Schwachmeyer, V., Graichen, F., & Bergmann, G. (2012). Spinal loads during position changes. *Clinical Biomechanics*, *27*(8), 754-758.

57 Rohlmann, A., Zander, T., Graichen, F., & Bergmann, G. (2013). Lifting up and laying down a weight causes high spinal loads. *Journal of Biomechanics*, *46*(3), 511-514.

58 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

59 Ng, T.P., Bussone, W.R., Duma, S.M., & Kress, T.A. (2006). Thoracic and lumbar spine accelerations in everyday activities. *Biomedical Sciences Instrumentation*, *42*, 410.

60 Manoogian, S.J., Funk, J.R., Cormier, J.M., et al., (2010). Evaluation of Thoracic and Lumbar Accelerations of Volunteers in Vertical and Horizontal Loading Conditions (SAE 2010-01-0146). Warrendale, PA, Society of Automotive Engineers.

61 Kavcic, N., Grenier, S., & McGill, S.M. (2004). Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. *Spine*, *29*(20), 2319-2329.

62 Nordin, M., and Frankel, V.H., (2001). Basic Biomechanics of the Musculoskeletal System, Third Edition. Philadelphia, PA, Lippincott Williams & Wilkins.

63 Morris, J.M., Lucas, D.B., Bresler, B., (1961). "Role of the Trunk in Stability of the Spine." The Journal of Bone and Joint Surgery, American 43-A(3): 327-351.

64 Chaffin, DB, Andersson, GBJ, Maring, BJ, (1999) Occupational Biomechanics, Third Edition, Wiley-Interscience

Personal Tolerance Values

According to the available documents, Ms. Prescott worked as a librarian which required moving and shelving books. Ms. Prescott also testified to running, swimming, biking, gardening, and kayaking as hobbies. These activities can produce greater movement, or stretch, to the soft tissues of Ms. Prescott and produce comparable, if not greater, forces applied to the body regions where biomechanical failures are claimed. Finally, numerous events that can occur while driving a car, such as contacting a pothole, crossing a speed bump/hump, and striking a parking curb can all produce an acceleration comparable to the subject incident.[65]

It is important to note that the peer-reviewed and generally-accepted technical articles cited throughout this report are included as support for the methodologies employed and the conclusions developed through my independent analysis of the subject incident. These scientific studies were not cited to simply be extrapolated to the subject incident and provide general opinions regarding the likelihood of occupant biomechanical failure following a motor vehicle incident. My conclusions are specific to the characteristics of the subject incident. My evaluation regarding the lack of a causal relationship between Ms. Prescott's reported biomechanical failures and the subject incident incorporated thorough analyses of the incident severity, occupant response, biomechanical failure mechanisms, and an understanding of the unique personal tolerance level of Ms. Prescott using peer-reviewed and generally-accepted methodologies.

Conclusions:

Based upon a reasonable degree of scientific and biomechanical certainty, I conclude the following:

1. On December 8, 2014, Ms. Patricia Prescott was the seat-belted driver of a 1991 Honda Accord that was stopped on a street in Federal Way, Washington, when the subject Honda was contacted in the rear at low speed by a 2003 Audi Allroad Quattro.

2. The severity of the subject incident was below 10 miles-per-hour, and more consistent with 5 miles-per-hour, with an average acceleration less than 3.0g and more consistent with 1.5g.

3. The acceleration experienced by Ms. Prescott was within the limits of human tolerance and comparable to that experienced during various daily activities.

4. The forces applied to the subject vehicle during the subject incident would tend to move Ms. Prescott's body back toward the seatback structures. These motions would have been limited and well controlled by the seat structures. All motions would be well within normal movement limits.

5. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Prescott's claimed cervical biomechanical failures. As such, a causal relationship between the subject incident and the cervical biomechanical failures cannot be made.

6. There is no biomechanical failure mechanism present in the subject incident to account for Ms. Prescott's claimed thoracic and lumbar biomechanical failures. As such, a causal relationship between the subject incident and the thoracic and lumbar biomechanical failures cannot be made.

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[65] Rudny, D.F., Sallmann, D.W. (1996). *Analysis of accidents Involving Alleged Road Surface Defects (i.e. Shoulder Drop-offs, Loose Gravel, Bumps, and Potholes)*. (No. 960654). SAE Technical Paper Series.

If you have any questions, require additional assistance, or if any additional information becomes available, please do not hesitate to call.

This preliminary analysis is intended for use by the addressee, who assumes sole responsibility for any dissemination of this document.

Sincerely,

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